Metallurgical and Chemical Engineering

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Copper in Converter Slags

THE tourist with metallurgical proclivities visiting the copper smelters in the Rocky Mountain region is struck by a very general similarity in most of their machinery and methods. This doubtless is a result of the evolutionary development of copper metallurgy during the last twenty years. Take, as an instance, the roasting department. It utilizes a furnace which is essentially a steel tank containing multiple superimposed hearths through which the ore is rabbled by cooled arms fixed to a rotating central shaft. Of course many variations in detail design may be noted, and the furnaces may therefore variously be called McDougall, Wedge, or Herreshoff. Furthermore, differences appear in methods of charging ore, removing calcine and handling smoke in adaptation to the general requirements of the plant and its surroundings. Still it is apparent that this type has exclusively supplanted the earlier heaps, stalls, straight-line and curved hearths, sintering pots and Brückner cylinders as a roaster for copper ores.

The great variation in the methods of handling converter slag is consequently quite suggestive of the diversity of opinion which prevails on this subject, and indicates that some, if not many, of the solutions have an insecure foundation on financial economy and metallurgical fact. Probably based on the idea, implied if not admitted, that the copper in these slags is held in complex compounds which cannot be broken up in the approximately neutral reverberatory furnace, many plants allow the slag to solidify and resmelt it in a blast furnace. The accompanying slag-casting machine may be a series of stationary or tilting pans, a chain of molds traveling in a straight line or about a "merry-go-round," or again the slag may be poured out in a thin layer on an ore bed, or even into a sump or a hole in the ground to be reclaimed later by steam-shovel or grab-bucket. If the plant possess no blast furnaces, or the management is willing to brave slag loss to save coke, the slag is charged into reverberatories. Here again considerable variation is noted; cars may be switched to the charging track and the liquid slag poured through the furnace roof with the maximum fall possible; pots may be poured by cranes into slag launders delivering the slag through the side or back wall at a moderate head, or finally cold skulls may even be used for "manger" filling.

After noting this diverse practice, it is not surprising to find little real information available on the fundamental question "How is the copper held in the converter slag?" or the broader one "How is copper held in a furnace slag?" If the intense oxidizing atmosphere in the converter forms copper oxides and silicates, then doubtless a powerful smelting process would be needed

for its retreatment, and hot-charging into the reverbera-
tory would merely dilute the slag loss. However, Laney
of the United States Geological Survey found after
microscopic investigation that the valuable metal even
in good furnace slag is mostly in a suspension of minute
spheres of matte; on this basis the whole question of
recovery becomes merely one of "hindered settling"
wherein the relative specific gravities of the matte and
slag, the size of the particles of matte, but more
especially the viscosity of the slag itself play their
separate roles.

Converter slags can be run so high in magnetite as
to be unworkably sticky. If the viscosity of furnace
slag is similarly affected by a more modest increase
in the iron content the contention of the metallurgists
at the El Paso plant is easily explainable, that in a
reverberatory furnace a low-iron slag will be low in
copper, whether or not converter slag is charged.
Again, Green's idea that converter slag should be poured
into a bath from a considerable head is justified, since
the large body of matte would tend to wash out the
smaller particles by actual physical contact. Lastly,
good recovery might be effected by mere settlement,
if sufficient time be given at a temperature high enough
to maintain a mobile melt. Whether this final alter-
native is economically possible is a question of such
importance as to warrant a considerable expenditure
in research. In any event, it would seem that a study
of the relation of iron content and temperature to the
viscosity of a molten slag would pave the way toward
a proper understanding of many furnace problems, as
well as to a rational solution of the ever more pressing
and vexing question of the proper elimination of iron
from the smelting system.

Fats From Petroleum

"WHY," asked the Italian savant, Professor Gia-
como Ciamician, "should we use only the fossil
energy of the sun?" Why drill for oil and run it
through pipe lines and distill it and chlorinate and oxi-
dize and reduce and worry and fret over making fatty
acids out of it, when their glycerides are already made
for us over beautiful, waving fields of corn and soya
beans and on tropic sands in cocoanuts,—not to mention
only a few of the rich sources of supply now at hand?

Nature's chemistry book is planned on different lines
from ours. She does not bother about the elements as
much as we do. She regards the elements as a sort of
cosmic underwear and elemental stuff is displayed only
occasionally. In natural synthesis the units are seldom
elemental. Nature also has physical chemistry in the
back of her head and she uses it as we use the multi-
plication table, without counting her fingers. It is the
same with the phase rule, and again she has mathematics
enough and all by heart to meet any number of phases.
Then she applies the rule to men and women, to our
utter confusion. In technology she introduces the
element of aesthetics and makes her chemical factories,
which are forests and fields, things of unspeakable
beauty. Usually we hide our chemical factories as
much as we can so that the least number of people
may see them, which is entirely right and proper—since
they look as they do. Again, Nature will not endure a
stink, permanently. We make them and live in them.

It seems more than likely that even if peace ever
comes again, the edible fats of mankind will be of vege-
table rather than animal origin. It stands to reason that
fats from soya beans and from other vegetal sources
are more economically produced than by feeding corn
to hogs and then killing the hogs. It even seems more
economical to press seeds than to buy industrial
reagents and then to burn trainloads of coal to recover
them.

The greatest advances that have been made of late
in the development of vegetable oils for human con-
sumption have been with cocoanut oil, of which the im-
ports into this country increased from 64,349,308
pound in 1916 to 163,091,004 in 1917. The soya bean
industry is promising and peanut oil is here to stay.
Cottonseed oil has long been a great American institu-
tion and corn oil is another aspirant for high office in
human economics.

So, while we would not stay the hand of any one en-
gaged in legitimate research, we have our favorites for
encouragement. Just now we should like to see greater
encouragement and interest in the work of biological
chemists. Someone has computed that the application
of the inventions of Louis Pasteur to industry produced
in three years sufficient wealth to pay the indemnity
demanded by Germany of France after the Franco-
Prussian war. Biological chemists produce the real
labor-saving inventions. With their yeasts and
ferments and miscroscopic critters they train vast
armies to work for us. It takes time to eliminate the
unfit and to train the fit; but they work beautifully
when they are started right. We have inherited ethyl
alcohol by this process, but it looks as though acetone
also were coming along pretty fast, and on a big com-
mercial scale at that. These methods may give us
glycerol some day, too, but as for the glycerides with
the complex fatty acids the work is already done for us
by the sun in the air. There is no reason to be satisfied
with things as they are, but there is every reason to be
appreciative, whenever we can. That is the cheerful
philosophy of research.

A Program
for Harmony

THE past two weeks have been eventful in developing
plans for harmonious relations between employer
and employee and fostering the spirit of the square deal
in industry. As reported in detail on another page
the War Labor Conference Board, appointed last
January at the instance of Secretary of Labor Wilson,
has recommended the creaton of a National War Labor
Board to settle by mediation and conciliation contro-
versies arising between employers and employees in
fields of production necessary for the effective conduct
of the war. By proclamation of the President the
National War Labor Board has since been appointed,
and all interested parties are urged by him to use the
means thus provided for the adjustment of industrial
disputes.

Undoubtedly quickened by a sense of national peril,
and realizing the necessity of unity in purpose and
action, representatives of the two great groups com-
prising our industrial life have sought and agreed upon
a basis for understanding during the war. Accepted

in principle by recognized leaders, there remains the more important problem of securing the active approval and sincere co-operation of the interested parties when occasion arises to test their professions. We have confidence that, in the main, the machinery provided in the Board will be effective and that it will not only contribute to industrial peace and harmony during the war but prove a large factor in all future relations between industry and workers. Primarily a fruit of war, the plan should be found effective as an agency for peace.

We may, however, regard one thing as certain. Public opinion is not going to be lenient with either party to the agreement who may violate its letter or spirit. The plan and purpose of the movement are sufficiently well defined to make it possible to place responsibility for broken pledges, and the public memory is likely to be more retentive than usual when it comes to remembering those who deliberately or tacitly impede the progress of the war by strikes or lockouts. Conciliation and mediation are the order of the day.

Another straw indicating the direction of the industrial wind, is the announcement of the plan for industrial representation of the employees in the Standard Oil Co. of New Jersey. Workers elected for the purpose by their fellows met and dined with high executives—captains of labor with captains of industry, as one engineer has put it—and plans of mutual interest were talked about and launched. Considering the success which a similar plan has met in the Colorado Fuel and Iron Co., controlled by the same interests, the New Jersey company may justly anticipate harmonious relations with its men.

The Steel Corporation

THE annual report of the United States Steel Corporation is issued for 1917 in its usual comprehensive form. The corporation's production of pig iron was 15,652,928 tons while the production of ingots was 20,285,061 tons. In both items there were decreases from 1916 to 1917, while the production by independents increased. The corporation's pig-iron production decreased about 2,000,000 tons, while the production in the industry as a whole decreased only 800,000 tons, showing that the independent production increased 1,200,000 tons while the corporation production decreased 2,000,000 tons. This divergence was due to the shortage of coke, which was experienced with particular severity by the Steel Corporation. No coke ovens were operated at capacity in 1917, and as the independents has made greater additions to capacity than had the corporation they had an advantage. The corporation resolutely refused to buy coke in the market, when the market was already crowded with buyers.

The above is the statistical explanation, the commercial explanation involving certain important details. The corporation had planned for larger coke-making capacity, but the difficulty of maintaining construction schedules was too great even for the Steel Corporation. An addition of 140 ovens has recently been completed at Gary, and there are now nearing completion, scheduled for at least partial operation by July 1, 640 ovens at Clairton, 208 at Lorain and 180 at Cleveland, making a total of 1,168 ovens, which are good for about 5,000,000 net tons of coke a year.

When the complete statistics of the American Iron and Steel Institute are compiled for 1917 they will show the coke consumption per ton of pig iron of all the blast furnaces, and beyond doubt an enormous waste of coke will be shown, caused by intermittent supplies and resultant bankings or slow operation. Even in the case of the Steel Corporation, which has large furnace groups and can manipulate its coke supplies to particular advantage—all its coke for use beyond Pittsburgh being consigned to the Conway yard for later routing—the coke consumption appears to have increased from 2,145 pounds in 1916 to 2,230 pounds in 1917.

An evidence of the effect of successive wage advances in the steel industry is furnished by the data given in the Corporation's report. There were three 10 per cent wage advances in 1916 and two 10 per cent advances in 1917. In 1913 the average salary or wage per day of all employees except general administrative and selling force was $2.85 a day. In 1917 the item had risen to $4.10, the 10 per cent wage advance of May 1 having operated for seven months and that of October 1 for only three months, while this month a 15 per cent advance goes into effect. From this it may be estimated that wages to be paid in future will average about 85 per cent above the average of 1913, the year before the war. Those wages were 50 to 60 per cent higher than wages obtaining in 1898. It is not only interesting, but important from a sociological and economic viewpoint, to note that in the latest wage advances the Steel Corporation has been the leader not only in form but actually in substance. The independents would not have initiated a wage advance this month, and some of them have criticized the advance which becomes general through the Steel Corporation's initiative.

The earnings the Steel Corporation reports for 1917 are $295,869,292, after paying interest on bonds of subsidiary companies, but before making allowance for bond sinking funds, depreciation, corporation bond interest, etc. This compares with $33,574,178 in 1916, the record year. This is the item that interests the shareholders, but the iron and steel manufacturing industry is interested in the total profits, before deduction of the Federal war taxes, as those are the earnings the mills and furnaces really made. It may be an incident of war that there was so large a margin between cost and selling price, but it is also an incident of war that the war taxes are levied. In the Corporation report as usually made all the taxes paid are stated in a lump sum, including municipal, county, state, etc. For 1916 this lump sum was $26,599,721. In the 1917 report the Federal taxes for 1916 are mentioned separately as having been $9,692,009, while for 1917 they were $231,465,435. This sum may be changed somewhat when adjustments are made with the Treasury Department. Comparison of the earning power of the plants may be made by adding Federal taxes to the reported earnings, this addition showing total profits of $343,266,787 for 1916 and $528,757,615 for 1917. These amounts are strictly comparable, being for each year the profits less all taxes but Federal, and less subsidiary company bond interest. The sums are subject to Federal taxes, bond sinking fund allowances, depreciation and similar items.

Readers' Views and Comments

Fats and Fatty Acids from Petroleum

To the Editor of Metallurgical & Chemical Engineering

Sir:—I believe the recent article by Dr. Gustave Egloff in METALLURGICAL & CHEMICAL ENGINEERING on the Snythesis of Fatty Acids from Petroleum merits some comment. To any one who has not had any experience in the synthesis or attempted synthesis of fatty acids and other derivatives from petroleum hydrocarbons, Dr. Egloff's article is somewhat misleading in its rather superlative optimism. There certainly is nothing in any work thus far published which would, by any stretch of imagination, warrant the statement that Germany may be feeding her population with synthetic fats made from petroleum.

The excellence of some of Dr. Egloff's previous articles might perhaps give the weight of authority to his statements on the fatty acid question, and I therefore feel that it should be pointed out that many of the claims made by authors quoted by Dr. Egloff are very far from good Anglo-Saxon truth. Perhaps the most prominent and most curious reference cited by Dr. Egloff is the work of Zelinsky. Zelinsky claims to have made fatty acids from petroleum hydrocarbons by preparing the Grignard magnesium complex of certain halogen derivatives of petroleum oils and reacting upon this with carbon dioxide. It is no reflection upon Dr. Egloff that he should have taken Zelinsky's work at its face value, but I suggest that any one interested may readily convince himself of the pure nonsense of commercial synthesis by this route by merely repeating, or attempting to repeat, Zelinsky's work. He will find that the yields are vanishingly small. The reasons for this are several, principal among which are the following:

1. The formation of the magnesium complex is exceedingly slow with derivatives containing more than eight or ten carbon atoms.

2. It is well known that the higher magnesium alkyl halides readily react with a second molecule of the original alkyl halide to give a hydrocarbon and magnesium halide. For example,

$$C_7H_{15}MgBr + C_7H_{15}Br \longrightarrow C_{14}H_{30} + MgBr_2$$
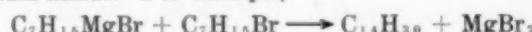
3. The halogen derivatives of petroleum hydrocarbons of ten to twenty or more carbon atoms are unstable and slowly break down on standing at room temperature to give free halogen acids and hydrocarbons which appear to be mainly saturated ring compounds. This behavior has not been published in any detail and I can cite no authority other than my own experience.

4. Stadnikoff in a series of comparatively recent papers showed that the alkyl magnesium halide and ether complex breaks down in a variety of ways. For example, Stadnikoff showed that a complex made from magnesium propyl iodide, carbon dioxide, and benzhydrylbutyl ether yielded a mixture of several hydrocarbons, free carbon dioxide and mixed ethers, only a trace of acid being obtained. He therefore states that the evidence gathered from a series of such studies points to the Grignard constitution rather than that of Baeyer, and suggests that the constitution of the compounds formed by passing in carbon dioxide is of the following type:

$$\begin{matrix}(C_6H_5)_2CH \\ C_4H_9\end{matrix}{>}O{<}\begin{matrix}C_3H_7 \\ CO_2MgBr\end{matrix}$$
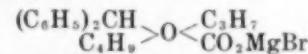
There are obviously many other lines of attack, but I wish merely to point out that the methods so far disclosed are of practically no value for the purpose of making fatty acids from petroleum, even for the purposes of laboratory research, let alone commercial synthesis. For example, it is known that fusion of the higher alcohols with caustic potash yields free hydrogen and fatty acids, but only the higher primary alcohols give good yields. The secondary alcohols are very slightly oxidized under these conditions and yield mostly condensation products. The higher tertiary alcohols break down, giving acids of less number of carbon atoms. Also it has been shown that the alcoholates of the higher alcohols react with carbon monoxide under high pressures, but the principal products formed are esters of formic acid and not the higher fatty acids. The known methods for preparing alcohols direct from petroleum olefines yield only secondary and tertiary alcohols. Also no methods for adding halogens or halogen acids to the saturated or unsaturated hydrocarbons are known which give high yields of primary derivatives.

It is true that numerous methods have been proposed for oxidizing saturated and unsaturated hydrocarbons by air in the presence of various other substances and a great many wet methods have been tried, but the sum total of the results thus attained may be briefly summarized with the statement that in general the results are carbon dioxide, water, resinous or asphaltic material, and traces of the simple fatty acids such as acetic, propionic, butyric acids, etc., which usually have not been obtained in quantities sufficient for positive identification.

It cannot be too strongly emphasized that the chemistry of the aliphatic hydrocarbons is practically limited to methane, ethane, propane, butane and pentane and their derivatives. We then skip to a large island of knowledge which includes the chemistry of the terpenes and the reason for the rich development of this latter field is doubtless the ready availability of raw materials found in natural products—the essential oils. The books usually discuss the chemistry of the simple compounds, such as ethyl alcohol, ethyl bromide, ethyl cyanide, ethyl amine, butyric acid, fusel oil, etc., and then stop, usually with the added statement that the reactions presented for these simple derivatives are type reactions which hold good through the rest of the series. It would require more space even to indicate that this is not so than would be warranted in this brief note. Personally I believe that reactions which do not give yields of more than 2 or 3 per cent of the theory should *not* be inflicted upon the unsuspecting student as type reactions.

Our chemistry of the aliphatic series is decidedly spotty. We have a well rounded terpene chemistry,

a beautiful sugar chemistry, a complex chemistry of the fatty acids, and well perfected industrial methods, etc., but thus far the chemistry of the petroleum hydrocarbons brings up the tail end of the procession. Curiously enough the great bulk of the hydrocarbon chemistry which will go far in serving as a basis of exact chemical knowledge of petroleum has been done in Russia, although our own country has been blessed, as no other continent, with its rich petroleum resources. Personally I share Dr. Egloff's optimism to the point of believing that the commercial synthesis of fatty acids from petroleum *may* *s*ome day be accomplished, but not by the methods of synthesis now known and not until we have built up a much more extensive and quantitative knowledge of the behavior of hydrocarbons, such as constitute petroleum oils.

<div align="right">BENJAMIN T. BROOKS.</div>

Flushing, N. Y.

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To the Editor of Metallurgical & Chemical Engineering

SIR:—I am so much impressed with the value of the information conveyed in the paper entitled "Fats and Fatty Acids from Petroleum," printed in your issue of March 15, that I cannot refrain from expressing my appreciation and my hope that the authors will, before long, be able to present the results of their further work along the lines indicated in a later paper.

While I am not sufficiently well versed in the intricate combinations of carbon and hydrogen molecules to follow intelligently all the reactions involved and given in this new line of research, I have long been impressed with a belief, amounting to conviction, that, sooner or later, the problem of transforming and converting petroleum hydrocarbons into fats and fatty acids would be solved. The earliest patents mentioned by the authors for methods of this nature date back to 1912, but doubtless long before that time the subject had occupied the minds of chemists, for the prize is a most tempting one.

In a brief paper which I had the honor of presenting before the American Society for Testing Materials at its convention in June, 1911, on "A Novel Method of Detecting Mineral Oil and Resin Oil in Other Oils" (see **Vol. XI, 1911**), I said:

"Chemists will, I believe, eventually solve the problem that has hitherto baffled all their endeavors, of oxidizing hydrocarbon or mineral oils and of rendering them saponifiable. The monetary value of such a discovery is incalculable and the solver of the riddle would at once rank among great discoverers."

The authors italicize this remarkable statement: *"It is not improbable that Germany to-day is supplying a large part of her fats from synthetic production."* If this be true, it becomes a matter of prime importance for our chemists to find a commercial process for the synthetic production of fats and fatty acids from hydrocarbons present in petroleum which the authors plainly indicate has already been, in a measure, successful, for they say in conclusion: "Fats and fatty acids from petroleum is more than an empty phrase."

I shall look for further information from them and I contribute this note with the view of calling the attention of your readers to the importance of their article.

<div align="right">ALEXANDER E. OUTERBRIDGE, JR.</div>

Philadelphia, Pa.

Ammonia, Refrigeration and Munitions

To the Editor of Metallurgical & Chemical Engineering

SIR:—I was much interested in the article entitled "Ammonia, Refrigeration and Munitions," on page 277 of the March 15 issue of your journal.

Ever since this discussion of shortage of ammonia and the cutting down of its use by refrigeration plants came up, I have wondered that nothing appeared in the literature with reference to the substitution of liquid sulphur dioxide for the ammonia, and for some weeks I have been on the point of addressing you on this subject.

For quite a number of years sulphur dioxide has been used successfully in Europe for this purpose. It has many other advantages over ammonia, besides its much lower working pressure. I think it is from lack of correct knowledge, more than from any disadvantage inherent in this material, that it has not been used more for this purpose in this country.

I must take exception to the statement in your article that "SO_2 does not behave well in iron," unless that statement be qualified. It is true that liquid sulphur dioxide that is not pure and dry does attack iron, but it is also true that liquid sulphur dioxide which *is* pure and dry does *not* attack iron. At least one company in this country is making small refrigeration machines which are much more delicate than large commercial installations, using iron entirely for the cylinder and piston of the compressor, and, I believe, in all other places with which the gas comes in contact. When the gas used in these machines is sufficiently pure and dry they have no trouble with corrosion.

It is by no means as simple a process as most chemists would think, not having concrete experience with the matter, to separate water from, and dry perfectly, sulphur dioxide, but with properly designed apparatus, properly handled, this can be done with ease and certainty. The writer has made liquid sulphur dioxide on a large scale that has satisfied the most exacting requirements along this line.

It is perfectly true that but little of the liquid sulphur dioxide manufactured in this country, at least until recently, has been pure and dry; a number of the plants with which the writer is familiar for making this material have had installations for drying that were really laughable in their absurdity. One manufacturer passed his gas first up through a tower filled with packing, down which flowed sulphuric acid, *and then through a tower filled with calcium chloride to catch any sulphuric acid sprayed over from the sulphuric acid tower.* After this careful (?) drying it was stored in a gasometer *over water*, before being compressed and liquefied. This is hardly more absurd than other installations I have seen. Is it strange, then, that much of the sulphur dioxide on the market is not anhydrous?

Interest in the manufacture of liquid sulphur dioxide is increasing in this country, new plants are being erected and old ones remodeled. A tank car of special design has been proposed in which to ship the liquid, to do away largely with the excessive cost of transportation of the heavy containers usually used in shipping this and other compressed gases. Inasmuch as the pressure over liquid sulphur dioxide at ordinary tem-

peratures is so much less than that of most other liquefied gases, the use of such a tank car is possible. I think we can look for a large increase in the use of sulphur dioxide in the near future. While it is true that to the uninitiated there are many odd and unexpected troubles, yet to one with the necessary experience its manufacture is simple and without complication. It can be made readily from much of the sulphur gases now forming a nuisance in many communities. It could be used to great advantage in many places where sulphur is now burned to get the dioxide and no doubt in many places where sulphites are now used. With the increase in the amount manufactured, we can look for prices to drop to a point where its greatly extended use will be possible.

STEPHEN R. MOREY.

Yonkers, N. Y.

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To the Editor of Metallurgical & Chemical Engineering

SIR:—In your issue of March 15 I note an article entitled "Ammonia, Refrigeration and Munitions."

In this article you state that sulphur dioxide cannot be used in ammonia compression systems. That "the pump and refrigeration pipes must be made of brass or copper for obvious reasons. SO_2 does not behave well in iron * * * ."

If you will investigate this subject further I think you will find that you are in error in this statement. Sulphur dioxide in our experience, which has extended over a period of about seventeen years, performs just as well in iron and steel systems as in copper or brass; the latter, however, have an advantage in the matter of heat conductivity. If the sulphur dioxide is pure and reasonably free from moisture, and the proper lubricant supplied, there would be no difficulty in substituting it in ammonia systems. It is essential, however, that the ammonia systems be cleaned of ammonia and oil before introducing the sulphur dioxide.

The capacity for a given displacement, of course, would be considerably reduced, but in many cases refrigerating machines could be speeded up so that the plants could be operated at from 60 to 70 per cent of their normal rating.

In many cases machines are operated only a part of each 24 hours. By increasing the number of hours of daily operation, sulphur dioxide could be successfully substituted for ammonia, and still maintain full service in many existing refrigerating systems.

E. T. WILLIAMS.

Electrical Refrigerating Co.,
New York City

* * *

The Food Administration at Washington, in urging the conservation of ammonia, has very properly taken the position that the only way to save it is to save it. It would not have been good policy to suggest the substitution of SO_2 so long as there is any doubt on the subject. The opinion was also expressed that the substitution of SO_2 for NH_3 cannot be made successfully in the great quantity of refrigeration apparatus installed throughout the country, *as things are.* The same opinion was vigorously asserted by certain leading refrigeration engineers whom we consulted in regard to the matter. And it was a leading authority who insisted to us that in the long run sulphur dioxide

refrigeration apparatus should not be constructed of iron. Our statement that "SO_2 does not behave well in iron" is open to the criticism that we should have said "moist SO_2." We took the moisture for granted because it is apt to be there.

But the problem involved is of far more importance than the correctness of our statements. There is prejudice as well as the fruits of research to be found in the art of refrigeration, and if prejudice stands in the way of progress we should try to remove it. The immediate problem is not to refrigerate with "properly designed apparatus, properly handled," but with the installations that are already built and duly set under all the eggs and fish. The drive is on, and all the ammonia there is—and then some more—is needed *now.* Let us admit that SO_2 may be suitably dried. Is it practicable to take a going concern now using ammonia, clean it speedily and effectively and shift over to sulphur dioxide without serious hazard of loss of stored merchandise or corrosion of the apparatus? Is it possible to test out such a change, using the same compressors, in a commercial plant of familiar design and thus prove that the substitution may be made generally? It would be a great boon, for it would release vast quantities of ammonia that are needed for munitions, provided it may be done now—right away. It would have to be done in existing apparatus without serious interruption of business.

If any of our correspondents has made the test and has the facts at hand, or is prepared to make the test to bring out the facts and prove that the change is practicable, our columns are open for him to tell the tale of it. We should be very glad to learn that in holding that the change cannot be made under existing circumstances, we were wrong rather than right. We are intensely interested in getting more ammonia for munitions and not at all vain about our own opinions.

EDITOR.

Sulphur Dioxide Method for Determining Copper Minerals in Partly Oxidized Ores

To the Editor of Metallurgical & Chemical Engineering

SIR:—Allow me to call your attention to an error in the article entitled "Sulphur Dioxide Method for Determining Copper Minerals in Partly Oxidized Ores," which appeared in your issue of February 15. Page 205, lines 26 to 29, inclusive, should read as follows:

"In general, when the solution to be standardized varies in strength from 1 to 3 per cent sulphur dioxide, add 1 cc. of this solution to 20 cc. of standard iodine solution. When the strength of the sulphur dioxide solution is appreciably below one per cent, add a larger quantity of this solution." The mixture is then treated * * *

This correction is essential to an understanding of the method presented.

CHARLES E. VAN BARNEVELD.

Tucson, Ariz.

Coming Meetings and Events

American Electrochemical Society, spring meeting, Southern trip, week of April 28.

American Society of Mechanical Engineers, Worcester, Mass., June 4-7.

Western Metallurgical and Chemical Field

Anaconda Company to Produce Ferromanganese

THE Anaconda Copper Mining Company will start immediately upon the construction of five electric furnaces of 4000 kw. capacity each for the production of ferromanganese, according to a statement by C. F. KELLEY, vice-president of the company. These furnaces will be installed in the present smelter building at Great Falls, which has ample room under the converter craneway. Consequently, with an excellent building and overhead cranes, a well-developed system for handling the materials and all the other auxiliaries at hand, the actual installation of the simple shaft furnaces will be a matter of a short time and dependent largely upon the procurement and delivery of the necessary transformers, electrodes and their automatic regulators. The necessary electric power, to the extent of about 20,000 kw., is already developed by the Montana Power Company, and can be delivered over present lines of large capacity connecting the Great Falls smelter to the hydroelectric plants farther down the Missouri River. Under such favorable conditions, it is hoped that the necessary special equipment may be procured by special arrangement, and the furnaces may be running by the middle of the summer.

The ores for their operation will come in large part from the Butte mines of the Anaconda Copper Mining Company, several of which have manganese-bearing oxides in their upper levels. In fact, a quantity of manganese ore has been collected from various shallow prospects and old dumps by ore-pickers and marketed through a local mill. In addition to these supplies, which will be fully exploited, the neighboring Phillipsburg district has been developed into one of the most important manganese producers in the United States, now shipping about 500 tons of 45 per cent ore daily, any necessary part of which may be diverted to the new furnaces. The plant is expected to produce 100 tons of ferromanganese per day.

Potassium Sulphate from Cement Dust

A rather unique and successful plant for the recovery of potassium from cement-kiln dust has been installed at the Southwestern Portland Cement Company by MR. J. G. DEAN, their chemical engineer. The cement plant is operating under the wet process, and the stack gases average about 40 per cent water vapor at a temperature of 600 deg. Fahr. They are first conducted through a dust chamber 200 ft. long placed underneath the kiln, where six or seven tons per day of the heavier dust particles are deposited. The gas then passes through a concrete flue to a fan, which delivers it to a spray chamber where a water spray brings down most of the remaining dust. The gases, heavily laden with the water vapor, are then sent to a condenser, and on being cooled the moisture begins to condense on any dust particles which may remain, and, of course, if these particles happen to contain potash, it is dissolved and washed out with the condensate.

This condensate is pumped into suitable tanks and is used as the condensing medium on the other side of the condenser tubes. The difference in temperature necessary is maintained by a vacuum of 24 in. (with a barometer of 27 in.), so that the installation, which, by the way, is entirely of reinforced concrete, is in effect a combined condenser and evaporator. This brine or condensate is eventually evaporated to saturation, when the potash salts crystallize out as sulphates.

It will be seen that this installation has considerably more evaporating than condensing capacity. In other words, they are condensing about 150 lb. of water per minute, and evaporating about 300 lb. per minute, which permits them to do any necessary extra scrubbing.

The chemistry of the process is very interesting. It has been found that by regulating the burning so as to maintain a slightly reducing condition in the kiln, the condensate holds in solution the following ions: K, Na, SO_4, CO_3 and S_2O_3. Some of the carbonates are changed to bicarbonates, and these serve to eliminate the sulphides. Since there is not quite enough of the sulphate ion to unite with all of the potassium ion, this deficiency is supplied by running the solutions through a bed of gypsum. This removes the carbonate ion and supplies the necessary sulphate and makes it possible to crystallize a very pure potassium sulphate, and at the same time produce a sodium thiosulphate of value.

There is no particular labor expense attached to the installation at the Southwestern Portland Cement Company other than the wages of one or two attendants necessary to take care of the collecting and refining apparatus. In other words, the flue dust collected will pay all the expense of collection and purifying, so that the potash is really so much profit.

Potassium Sulphate from Alunite at Marysvale, Utah

The rebuilt plant of the Mineral Products Corporation at Alunite, near Marysville, Utah, has started operations and is producing twenty tons of 97 to 98 per cent potassium sulphate per day. The original plant was constructed by Westinghouse, Church, Kerr of New York, and was admittedly of experimental nature. It was highly successful, however, and immediately after the fire of Oct. 25, 1917, a contract for reconstruction was placed with the Industrial Engineering Company of Salt Lake City. Current reports that the fire which destroyed the leaching, evaporating, storage and power buildings was of incendiary origin are incorrect, as the source was undoubtedly a spontaneous fire in the coal-pulverizing plant.

The general plan of the new works follows that of the old, with minor modifications found desirable by the early operations. Fortunately the evaporators themselves were damaged but slightly, and the crushing department and kiln rooms uninjured. Briefly, the process in use is as follows: The alunite, a moderately hard, brittle mineral (a hydrated double sulphate of potassium and aluminium) is first crushed to about 1-in. size and then roasted in a rotary kiln much like the familiar cement kiln, a brick-lined cylinder 7 ft. 6 in. in diameter and 135 ft. long, fired with pulverized coal. The calcined material is then leached with hot water in a closed tank at a temperature corresponding to 60 lb. steam pressure, which takes the K_2SO_4 into solution. The larger pieces of insoluble siliceous material are unaffected by this digestion, and are removed

from the liquor by merely screening. The solution is then filtered in a Kelly filter-press, which removes the fine solids—largely Al_2O_3 minus 300-mesh, together with a small percentage of silica and iron oxide. The clear filtrate is then evaporated in Swenson triple-effect evaporators, when the resulting crystals are centrifuged and sacked for shipment.

The company is planning to take up the matter of disposal of by-products as soon as the new plant attains its rated capacity of 30 tons of potassium sulphate per day. The alunite mined by the Mineral Products Corporation is contaminated with a relatively small amount of impurities. The coarse screenings, silica and aluminium silicates should therefore make excellent refractories, while the filter-cake, if it can be purified of the small amount of iron and silica it contains, should be converted into aluminium metal or aluminous abrasives.

Placer Platinum in California and Oregon

Chemists and metallurgists have long been interested in the high price of platinum which has all but prohibited purchases of new scientific equipment made of this element. Its absolute necessity as a munition is further emphasized by a war department order issued early in March requisitioning all crude and unworked platinum in the hands of importers, jobbers and wholesalers.

The platinum metals are found in quantities of economic importance at only a few places. The bulk of the world's production has heretofore been furnished by the placers of the Ural mountains, in Russia, but the production from this source is decreasing, while Colombia is becoming an increasingly large producer. Under normal conditions the United States requires about 165,000 oz. a year, while we produce only a few thousand ounces, and have met with increasing difficulties in importing sufficient supplies. The only considerable recent importation was a lot of about 21,000 oz. collected in Russia by Norman C. Stines, managing director of the Sissert Mining District Company, and brought to America in the baggage of a returning engineer, S. W. Draper.

The small American production, aside from that recovered from the refining of blister copper, is almost entirely recovered incidental to gold placer mining operations in California. At periods of about fourteen days the gravel contained in the sluices is cleaned up and the waste washed out with a hose stream, leaving behind a small pile of sand and amalgam. This material is again washed over a smaller riffled sluice containing traps for the "quick," and the resulting black sand containing the platinum, with some gold, osmium and iridium, is shipped to a refinery. Jas. W. Neill* estimated that a 3¾-ft. dredge mining about 68,000 cu. yd. per month was losing apparently 4.75 oz. of recoverable platinum per month, against a total caught and saved in the riffles of about 1.85 oz., and he installed a small Wilfley table to retreat the 20-mesh hutch product of jigs set below the sluices to catch tramp amalgam. It would be too much to expect the sixty-five million yards of gravel dug annually by the dredges in California to produce platinum at this average rate (1 oz. per 10,000 cu. yd.) since the output, 6500 oz. of platinum, would then far exceed the total of 710 oz. produced during 1916. Doubtless much more could be recovered by intelligent effort before the additional cost would overbalance the returns.

Smoke Purification at Anaconda

Shortly after operations at the Washoe Plant were started by the Anaconda Copper Mining Company some fifteen years ago, it was seen that the plan of having individual smokestacks for each department was causing considerable smoke damage to the surrounding country, and heavy expenditures were immediately undertaken to provide long flues connecting the various furnace buildings to a much wider hopper-bottomed flue acting as a dust chamber and leading up the hill to the "big stack" 30 ft. in diameter and 300 ft. high. In this way this pioneering organization showed their faith in that palliative which the most recent and painstaking research has shown to be the only known commercial method of disposal of dilute sulphur dioxide; that is to say, adequate dissemination in the upper atmospheric strata.

The continual increase of the amount of ore treated in this huge smelter has gradually overloaded even this flue system. Klepinger's studies, and the resulting flue system and stack at Great Falls, amply demonstrated the financial advantage of making adequate clearance of the solids, while additional pressure was brought to bear on the company by the final decree of their numerous and hard-fought "smoke suits." In the meantime, Dr. Cottrell's system for smoke clearance had been closely investigated, both in large and small-scale tests, and it was finally determined to build such a treater capable of handling the entire gases of the smelter (some 2,000,000 cu. ft. per minute). This program calls for an initial expenditure of about $2,500,000 and is well under way at the present time; wagon and railroads up the hill to the site are completed, and the excavation and foundation work is finished.

The new treater and stack will be located on a high ridge leading to the south of the present 300-ft. stack. The gases will be drawn from the top and end of the old flue where it branches out to either side before entering the old stack, through a double flue alongside a treater plant located beyond both chimneys, and thence back into the new chimney through flues placed between the treater structures. The chimney will be constructed of locally made brick, and will be 60 ft. inside diameter at the top and 525 ft. high, and is thought to be the most massive in existence, comparing in bulk with the Washington monument.

The treater plant itself will originally contain twenty sections, in two parallel lines of ten each, and will use "box-type" passageways, consisting of corrugated iron partitions for dust collecting, 12 in. apart, with a series of electrified chains suspended between 5-in. centers. The voltage used will be 75,000. Sufficient ground area has been prepared for doubling the treater construction, should it prove desirable in the future.

The recovered dust will be smelted nearby in a large modern reverberatory furnace, producing a matte containing the metallic values. The gas from this furnace will pass through a hot treater, recovering the true dust it contains for return to the furnace, and a cold treater, will precipitate the condensed metalloids, largely As_2O_3.

*Mining and Scientific Press, Dec. 8, 1917, page 828.

Important Developments Relating to Labor and Capital

**National War Labor Board Recommended by Representatives of Employers and Emlpoyees.
Standard Oil Co. of New Jersey Introduces Industrial Democracy.
Mining Engineers Discuss Labor Problems**

THE War Labor Conference Board composed of five representatives each of employers and employees, and two representatives of the public, appointed some time ago at the suggestion of Secretary of Labor Wilson to aid in the formation of a national labor program for the period of the war, has made its report and recommendations as follows:

That there be created for the period of the war a National War Labor Board with the following functions and powers:

1. To bring about a settlement by mediation and conciliation of every controversy arising between employers and workers in the field of production necessary for the effective conduct of the war.

2. To do the same thing in similar controversies in other fields of national activity, delays and obstructions which may, in the opinion of the National Board, affect detrimentally such production.

3. To provide such machinery by direct appointment, or otherwise, for selection of committees or boards to sit in various parts of the country where controversies arise, to secure settlement by local mediation and conciliation.

4. To summon the parties to the controversy for hearing and action by the National Board in case of failure to secure settlement by local mediation and conciliation.

In case the National Board is unable to effect a voluntary settlement or agree upon a decision, an umpire shall be chosen by unanimous vote or drawn by lot from a list of ten persons nominated by the President of the United States. No cognizance will be taken of a controversy between employer and workers in any field of industrial or other activity where there is by agreement or federal law a means of settlement which has not been invoked.

In their capacities as mediator or conciliator the Board or the umpire shall be governed by the following principles:

No Strikes or Lockouts During the War

The right of workers to organize in trade unions and to bargain collectively, and the equal right of employers to organize in associations and to bargain collectively, is recognized and affirmed, and shall not be denied, abridged or interfered with by either party. Employees should not be discharged for membership in trade unions, nor should they use coercive measures to induce persons to join their organizations, nor to induce employers to bargain or deal with them.

Present conditions as to union, non-union or open shops are to continue. Established safe-guards and regulations for health and safety shall not be relaxed. Women employed on work ordinarily done by men must be allowed equal pay for equal work. The basic eight-hour day is recognized as applying in all cases in which existing law requires it. In all other cases the hours of labor shall be settled with due regard to governmental necessities and the welfare of the workers.

Maximum Production to be Maintained

The maximum production of all war industries should be maintained, and methods of work and operation on the part of employers or workers which operate to delay or limit production, or which have a tendency to artificially increase the cost thereof, should be discouraged.

For the purpose of mobilizing the labor supply with a view to its rapid and effective distribution, a permanent list of the number of skilled and other workers available in different parts of the nation shall be kept on file by the Department of Labor, the information to be constantly furnished by the trade unions; by state employment bureaus and federal agencies of like character; by the managers and operators of industrial establishments throughout the country.

The recommendations recognize the right of all workers, including common laborers, to a living wage. In fixing wages, hours and conditions of labor, regard should always be had to the labor standards, wage scales and other conditions prevailing in the localities affected. Minimum rates of pay shall be established which will insure the subsistence of the worker and his family in health and reasonable comfort.

Standard Oil Co. Launches Industrial Plan

On April 1 a group of the officials of the Standard Oil Co. of New Jersey and some seventy delegates elected by the workmen in the New Jersey plants met at dinner at the company's offices in New York. The announced purpose was to bring employer and employee together for the free discussion of matters of mutual interest. It was definitely stated that there was not the slightest strain in the present or prospective relations between company and workmen, and that the idea of meeting together was to effect still closer relationship and insure continued harmony between the company and its employees.

The dinner marked the beginning of industrial representation among employees in the Standard Oil Co. A consequence of far reaching importance is the practical assurance of harmony in the organization during the war. Considering the importance of petroleum and its products it is highly desirable that there should be no disturbances in oil-producing concerns.

President TEAGLE announced an increase in wages effective April 1, averaging 10 per cent., applicable to all wage earners except first-class bricklayers and watchmen whose rates are increased 5 per cent, and lead burners whose rates were previously increased.

C. J. HICKS, executive assistant to the chairman of the board, explained certain plans which the company has for its employees, including a system of benefits and annuities. Arrangements are to be made whereby all

employees, after one year's service, without cost to themselves, shall be given an individual life insurance policy. One year's service carries a death benefit equal to three months' full pay; two years' service, five months' full pay, and so on progressively, until five years and over carries the equivalent of twelve months' full pay, with a minimum of $500, and a maximum of $2000.

Annuities are planned on the basis of a regular allowance of 2 per cent. of salary for each year of service for all employees at the age of 65 years, after twenty years' service, with a minimum of $300 per annum and a maximum of 75 per cent. of salary. Special provisions are made for employees less than 65 years of age, retired after twenty and twenty-five years of service.

Regulations were proposed governing the discharge of employees, and a list of offenses was agreed upon for which alone a man shall be subjected to summary dismissal. For other offenses the employee is to have due warning before dismissal. In case of possible injustice, the privilege of higher appeal is reserved to the worker.

Plans are under way for improvements in sanitation and housing at the company's plants. These were explained in detail by Mr. Hicks, who announced that Mr. Rockefeller had subscribed $50,000 to the Bayonne Housing Corporation and had donated that stock to the new Bayonne Y. M. C. A. toward the construction of which he had also given $100,000.

MINING ENGINEERS DISCUSS LABOR PROBLEM

At the April meeting of the New York Section of the American Institute of Mining Engineers the evening was devoted wholly to a discussion of the labor problem. Following is a report of the proceedings.

MR. SIDNEY J. JENNINGS, vice-president of the United States Smelting, Refining & Mining Company, traced the origin of the company from its inception to the present time. He found that the fundamental idea of the company and of the issuance of shares was one of co-operation. He then analyzed the present relation of the company to industry and said that if the company was not fulfilling its proper function it might have to be abolished. He found three dangers besetting the proper conduct of the modern company. First, the capitalist becomes divorced from a sense of personal responsibility in the operation of the business; second, the actual manager or management may have considerable power without having any capital interest in the concern; and third, the laborer or worker feels that he is only a cog in the big wheel.

Mr. Jennings suggested the following methods for overcoming the feeling which the laborer has that he is only a cog in the machine. He cited the fact that the United States Steel Corporation offers actual partnership through the purchase of shares in the corporation. Second, he thought that profit-sharing above a fair return was one of the best means of making the company a true co-operative agent. Third, he felt that a central employment manager was almost essential to maintaining harmonious relations between the company and the workers. A good employment manager can be responsible for either the good-will or the ill-will of employees which in turn means success or failure of the institution.

MR. WALTER DOUGLAS of the Phelps, Dodge Corpora-

tion operating copper mines in Arizona, said that it was becoming increasingly difficult to get the viewpoint of the wage earners due to the increasing numbers of men employed by individual companies. He contrasted former conditions when the employer, manager or shift-boss had so few working under him that he knew them all personally and could get their viewpoints very readily, with present conditions where concerns have thousands and tens of thousands of men in their employ without the possibility of knowing them all personally or getting their point of view. He thought that some substitute must be found to bring about the close personal touch which formerly existed in the small companies. He spoke of the necessity of getting specialists to analyze labor problems for companies and thought that engineers should be the first to seek the aid of such specialists. He thought that the manager of a concern is not suited to this particular kind of work and yet he is the one who most frequently tries to solve the problem himself. Mr. Douglas believed that the solution will be found in some intermediary between the employer and the employee, and stated that the labor union has not yet filled this gap. He was quite certain that the big problem in the labor situation is not one of wages or hospital dues or any such item, but rather the thousands of little things that the company knows nothing about until a crisis comes. It would be the duty of an intermediary to know what these things are and to correct evils before they develop into crises. The type of man best able to deal with labor would be one who has been a leader of labor himself, and he cited Secretary Wilson and Mr. Mitchell as types who would be good intermediaries for large concerns. Speaking for the Phelps, Dodge Corporation he said that they had an employment agent at the Copper Queen mine whose duty it was to employ, transfer and dismiss all workers. The foreman of any department could not dismiss a man but was obliged to inform the employment manager that the man was not suitable for that particular work, whereupon the employment manager would transfer him to some more suitable place. The company has a pension system for those who have worked for the company for fifteen years. The pension is 2 per cent. of the salary for the number of years worked, and has a maximum of $1000 per annum. The company operates a benefit association to which 80 per cent of the employees belong. The company contributes about an equal amount with the employees. This past year an experiment was made in offering a flat service bonus of $100 to every man who had worked for the company one year. This was offered without regard to his position or salary and was a straight premium for sticking to the job.

TARGETS OF LABOR AGITATORS

Mr. Douglas said that the points on which the labor agitators had played most strongly were the company store and the hospital. He showed that the company store reduces the cost of living and that only recently 90 per cent. of the employees at Ray, Miami and Globe had petitioned his organization to establish company stores at those places. He felt that the hospital is a different problem and that if the company does not run it, it will not be run right and the men will not receive adequate attention. The charge for this service is nom-

inal and yet the agitators always find a good deal of fault with both the company store and the hospital in spite of the fact that both institutions are for the good of the employees. Mr. Douglas then touched briefly on the work of the president's mediation committee which settled the recent fight in Arizona. This report has been published by the U. S. Department of Labor.

MR. J. PARKE CHANNING said that while the United States had been efficient as far as methods and processes are concerned, we have not been efficient in the utilization of our man power. He cited the change which has taken place in England since the beginning of the war and showed that England had become a socialistic community which was highly efficient, with the government doing almost everything. He said that the English laborers were not going to be content to return to the old order of things. He admitted that the problem in Great Britain was simpler than in the United States on account of the fact that practically all of England's laborers are English, while the United States has a mixture of unassimilated foreigners. He felt that if we are to carry the war to a successful conclusion and increase our efficiency after the war we must Americanize our foreigners and give them our own point of view. He then outlined the proposed program of the British labor party which has four principles or pillars, namely,

1. Universal enforcement of the national minimum.
2. The democratic control of industry.
3. The revolution in national finance.
4. The use of surplus wealth for the common good.

If these four demands are carried out, England will be a socialistic state. Mr. Channing did not presume to say how much this program could or should be carried out but cited it as showing the trend of thought in England.

The British workman has seen his wages increase and he is more than ever convinced that in the past he had not been getting his fair share of the products of his toil. Mr. Channing also believed that the workman was realizing that he had not done his proper share toward increasing the wealth of the country. Generally speaking the British workman has seen such good results obtained in the democratic control of industry during the war that he feels that such control should be just as efficient after the war. Mr. Channing distinguished between the English labor party and the Bolsheviki of Russia, saying that the former did not believe that the working class should manage the country; that the English labor realized the importance of brains and education and the necessity of these things in bringing the country to the highest state of development. He felt that a program similar to that in England was likely to come up in the United States and that we should be on our guard lest the pendulum swing too far, as it is likely to do if the employing class does not give more attention to the worker and see that his condition is improved. He felt that engineers were the best instruments for carrying out the necessary work. He spoke of the growing tendency to give engineering students some training in human engineering and cited such courses at Columbia University. In discussing trade unionism he said that Professor Hoxie's work on Trade Unionism in the United States would clarify anyone's ideas of that subject and suggested that the book be read by all engineers. He spoke very favorably of the work of the industrial department of the Y. M. C. A. in human engineering.

SUCCESS OF CONCILIATION BOARD IN ANTHRACITE FIELD

MR. EDWIN LUDLOW, vice-president of the Lehigh Coal & Navigation Company, agreed with Mr. Schwab that "labor is now in the saddle." He said that the time had come when we must have captains of labor as well as captains of industry and that both of these factors must get together if we are to have the best development of industry. He reviewed conditions in the anthracite fields of Pennsylvania beginning with the strikes some years ago which were settled by Mr. Roosevelt. He explained the nature of the commission which was established at the time and reviewed the document which that commission drew up and which has stood the strain of fifteen years of active application. The most important feature of the method of settling disputes was the establishment of a board of conciliation which was the final arbiter. Another important point was, that pending the adjudication of any disagreement there should be no suspension of work either by lockout or strike. Mr. Ludlow thought that we made a mistake if we do not encourage the better class of men to join the union so that those organizations will be directed by the best thought among the laborers.

DR. E. E. SOUTHARD, a physician and one of the directors of the Psychopathic Hospital of Boston, spoke of the possible use of the psychologist in handling labor for large organizations. He felt that there was a reasonably good field already developed for this type of scientist in assisting large concerns to get the right men for the right jobs and to analyze a good many conditions which are purely psychological in their character.

MR. R. J. YOUNG of the Illinois Steel Company told what that organization had done in a very elaborate way toward taking care of its employees and trying to establish harmonious relations between the workers and the company. He laid considerable stress on the idea of an employment manager whose function it was to secure a desirable labor supply. He spoke of part ownership by employees and suggested that when a certain percentage of the total stock was owned by employees they should have representation on the Board of Directors of the company. With regard to pensions he raised the question as to whether the amount paid should be based on the wages of the man or on his ethical value to the company. He thought that basing a pension solely on the wages previously earned was not wholly a fair method. Mr. Young then outlined very briefly the numerous activities engaged in by the steel corporation in an effort to create good working conditions and establish harmonious relations between the company and the men. Among these efforts were medical supervision, dental clinics, shop sanitation, industrial canteen, domestic science instruction for the laborers' wives, proper illumination of shops and homes, fire prevention, proper ventilation, recreation for the workmen and their families, education for the children, housing and insurance. He laid considerable stress on the value of picking proper individuals for foremen because they represent the management to the men and hold very important positions in the organization.

The Solubility of Paraffins, Aromatics, Naphthenes and Olefins in Liquid Sulphur Dioxide

A Study of the Possible Utility of Liquid Sulphur Dioxide in Oil Refining and Analysis. Solubility of Pure Substances and Separation of Mixtures

By ROBERT J. MOORE, J. C. MORRELL AND GUSTAV EGLOFF

IN THE analysis and refining of oils, the question of procedure has long been a vexed one. Methods for the determination and isolation of the various constituents of natural petroleums and artificial oil mixtures follow no general scheme and are of questionable accuracy. The well known sulphonation for olefins and nitration for aromatics have long been used as more or less approximate tests for the want of something better. Moreover with this method the unsaturated and aromatic hydrocarbons are lost, since their recovery from the acid sludge is difficult, and their physical properties therefore are based on calculation of the oil before and after treatment, giving questionable results. The present paper is a contribution to the analytical and refining methods on hydrocarbon oils based on their solubilities in liquid sulphur dioxide.

In 1892 Walden[1] used liquid sulphur dioxide as a solvent for many inorganic and organic substances, dissolving, among others, benzene, phenol, naphthalene, aniline and diphenylamine. This property of liquid sulphur dioxide to dissolve certain organic substances was used by Edeleanu[2] in the refining of crude petroleums. He found that "if a distillate is agitated with liquid sulphur dioxide at a low temperature the aromatic compounds are dissolved but the paraffins and naphthalenes are unaffected." With this as a basis he evolved the process bearing his name, which has been used to some extent in Italy and Germany. In his paper Endeleanu shows the efficacy of his process in refining many illuminating oils and compares results with the ordinary methods of refining. He finds also that liquid SO₂ has a marked effect in removing certain sulphur-bearing compounds along with the aromatics.

The admirable work of S. E. Browery[3] which has recently come to the authors' attention takes up the refining with liquid sulphur dioxide in more detail. Using Edeleanu's method at —12°C. Browery found that conditions applied to purifying lamp oil do not hold for lighter fractions. For example, at —12°C., the lamp-oil fraction from a Trinidad crude, treated three times with half its volume of sulphur dioxide gave highly satisfactory separation. On the other hand a light distillate (up to 150°C.) from the same crude yielded extracts containing about equal parts of aromatics and paraffins. By working at lower temperatures than —17°C. it was found possible to improve results up to a point at which satisfactory correction could be applied by means of specific gravity determinations. A series of extractions run on artificial mixtures containing about 15% aromatics and using temperatures to —35°C. (Obtained by evaporating liquid SO₂) showed fairly accurate results. The method was applied to the determination

and recovery of toluene in crude oil from Trinidad Central. Browery states that "naphthenes are insoluble in SO₂ and are therefore left with the paraffins."

Rittman and Moore[4] in 1915 published a note on the liquid SO₂ method of separating aromatics from paraffins. Their results show fairly good separations for low percentages of aromatics but not on higher percentages. In their work which was merely a preliminary note on method, the burette was embedded in ice and salt mixture and its removal for volume reading took time and made temperature readings uncertain.

SCOPE OF PRESENT WORK

The literature contained no work on the individual solubility in liquid sulphur dioxide of the various hydrocarbons. As this seemed essential to any comprehensive work the curves of various pure compounds were determined. The results on naphthenes were contrary to the statements of both Edeleanu and Browery and are discussed later. The solubility of the following dydrocarbons was determined: Pentane plus hexane, hexane, octane, nonane plus decane; washed gasolene, washed kerosene; benzene, toluene, xylenes, mesitylene; hexalene, caprylene; cyclohexane and naphthenes boiling within the following limits, 75°-155°, 155°-175°, 175°-185°. These solubilities were determined at temperatures of —10°C. and —18°C. A series of SO₂ treatments was then run on a number of synthetic mixtures and results tabulated.

PROCEDURE

A modification of Edeleanu's apparatus was used as illustrated in Fig. 1. The oil to be treated was run into the graduated burette, then placed in the cooled alcohol bath and its volume read, the temperature of the bath being recorded on a toluene thermometer. A zinc tube embedded in a freezing mixture of ice, salt and calcium chloride served as the container for the alcohol bath, the outer container being well insulated with heavy felt. It was found that this apparatus could be kept at almost constant temperature over a range of 75 minutes for the lower temperature. The liquid SO₂ was run in from a tank through heavy-walled rubber pressure-tubing. The volume of SO₂ was read off as the increase in volume in the burette. A modification of this was used on mixtures. The SO₂ was first run out into a glass stop-cocked closed burette. This burette was then attached by means of heavy rubber tubing to the burette containing the oil and the volume of SO₂ used read off on the first burette. If separation into two layers occurred, both volumes were read. Burettes of various capacities were used depending on the volume of oil to be treated or the volume of SO₂

[1] Ber., 32,2862, 1899.
[2] Bull., A. I. M. E., 93,2313, 1914.
[3] Pet. Rev., 36,351,385,401, 1917.

[4] Met. & Chem. Eng., 13,713, 1915.

to be added. The separated layers were run off into different tubes and the SO₂ separated either by evaporation or by solution in dilute sodium hydroxide, after which the separated oils could be measured and their specific gravity and indices of refraction determined. The latter were measured with a Pulfrich refractometer. Specific gravities were taken with a Westphal balance where possible or with a 1-cc. pycnometer.

In several instances, where minute quantities of one or two drops were separated, a special method had to be devised for the accurate determination of such small quantities. The method finally adopted may prove useful to experimenters in determining this physical constant of minute quantities, one drop of the substance being sufficient for a number of measurements. The method employed was as follows: A two or three-inch piece of fine, thin-walled, capillary tubing is weighed on an accurate balance to the fourth decimal place. Then, held upright in a small pair of weighing forceps, the lower end is dipped in the drop of substance which immediately fills the entire tube due to capillarity. As soon as it is filled it is placed on the pan of the balance and weighed again, the increase giving the weight of the substance. The tube is then cleaned and its volume determined by weighing filled with water. The specific gravity is then calculated for the temperature at which the tube was filled. If the substance under examination is highly volatile, the capillary tube as soon as filled may be placed in a small glass-stoppered weighing bottle. This method was checked up by the Westphal balance on toluene, benzene, and alcohol and gave satisfactory results on volumes as low as 0.012 cc.

HYDROCARBONS USED

The physical properties of the oils used are given in groups in Table I.

TABLE I. PARAFFINS

Name	B. P. °C.	Sp. Gr. (Westphal) 15.5° C.	(Pulfrich) Index	Treatment with Conc. H₂SO₄ and Conc. HNO₃
Petroleum Ether (Butane, Pentane and Hexane)	Below 50°	0.643	1.3629	No coloration
Pentane and Hexane	55–65°	0.650	1.3700	No coloration
Hexane	68.8°	0.655	1.3734	No coloration
Octane	125.4–125.6	0.706	1.3999	No coloration
Nonane and Decane	156–159	0.730	1.4174	No coloration
Gasolene *	50–175	0.721	1.4008	No coloration
Kerosene *	120–250 = 89%	0.779	1.4277	No coloration

Aromatics

Name	B.P.°C.	Sp. Gr. 15.5°C.	Index	Remarks
Benzene	80.2–80.4	0.880	1.5014	No coloration with 1.84 H₂SO₄
Toluene	109–110.2	0.870	1.4982	No coloration with 1.84 H₂SO₄
Xylene (p-xylene)	138	0.880	1.4961	No coloration with 1.84 H₂SO₄
Mesitylene	162–163.5	0.870	1.4991	No coloration with 1.84 H₂SO₄

Olefins

Name	B.P.	Sp. Gr.	Index	Remarks
Hexylene	68°	0.689	1.3994	Combined completly with 1.84 H₂SO₄
Octylene	121–124	0.724	1.4145	Combined completely with 1.84 H₂SO₄

Naphthenes

Name	M. P.	B. P.	Sp. Gr.	Index	Remarks
Cyclohexane	6.4°	80–80.2	0.780	1.4255	No coloration with H₂SO₄ or HNO₃
Naphthenes		75–155	0.784	1.4267	
Naphthenes		155–175	0.799	1.4345	No coloration with H₂SO₄ or HNO₃
Naphthenes		175–185	0.809	1.4379	No coloration with H₂SO₄ or HNO₃

* The gasolene and kerosene were distilled from Pennsylvania crude, washed repeatedly with fuming sulphuric acid, neutralized with dilute sodium hydroxide, washed with water and dried over calcium chloride.

The cyclohexane was a particularly pure specimen melting at 6.4°C. The sulphuric acid and nitration tests

showed no trace of either olefins or aromatics, and the absence of paraffins was sufficiently proven by its specific gravity, index of refraction and sharp freezing point.

The higher boiling-point naphthenes used were distilled from naphthene-base oil distillates used in a previous research.[1] The following fractions were used: Boiling points 75°-155°, 155°-175° and 175°-185°. These were washed free from olefins and aromatics. The specific gravity and index of refraction of these fractions indicate their nahthenic nature. In Table II these values are compared with the physical properties of pure paraffins and pure naphthenes.

TABLE II.

Boiling Point Range °C.	Pure Paraffins *	Pure Naphthenes *	Oil Used
75–155	Sp. Gr. —0.712	0.778	0.784
	Index —1.411	1.429	1.4267
155–175	Sp. Gr. —0.730	0.798	0.799
	Index —1.413	1.44	1.4345
175–185	Sp. Gr. —0.745	0.803	0.809
	Index —1.4158	1.433	1.4379

* Values taken from Engler—Hofer, Das Erdol.

The paraffin and naphthene hydrocarbons are almost identical in their inactivity toward reagents, and therefore offer difficulty in distinguishing one from the other. But if we know that an oil is free from olefins
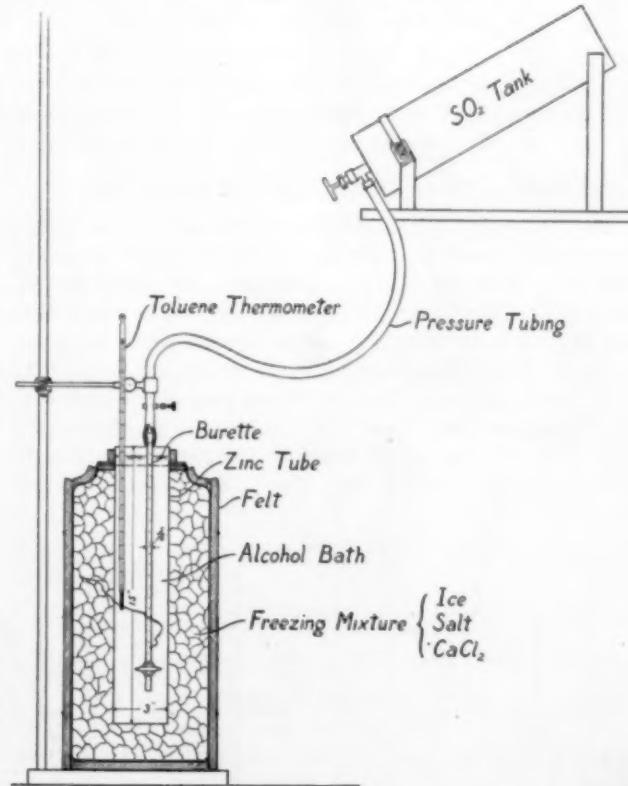
FIG. 1.

and aromatics, through sulphonation and nitration, specific gravities and refractive indices are sufficiently wide apart to distinguish pure naphthenes from pure paraffins. The above table shows that in each case the properties of the oil used closely approximated the values for the pure naphthenes, and were sufficiently higher than the value for paraffins to assure absence of the latter. The difference in their behavior with the liquid sulphur dioxide checked up their difference in chemical structure.

[1] Egloff and Moore, Met. & Chem. Eng., XV, 6, 1916.

SOLUBILITY OF AROMATICS IN LIQUID SO₂

The solubility of pure aromatic hydrocarbons in the liquid SO₂ is shown in Graph I. Two different percentages of liquid SO₂ were used, 33.3% and 66.7% and two temperatures —18°C. and —10°C. The four aromatics used, benzene, toluene, xylene and mesitylene were completely miscible in all cases. In using the benzene which freezes at 6°, the SO₂ was run into the kerosene at room temperature, shaken and then placed in the bath. With 33.3% SO₂ only a slight turbidity was visible due to a tendency of the benzene to freeze.

SOLUBILITY OF PARAFFINS IN LIQUID SO₂

The insolubility of paraffin hydrocarbons is shown in Graph I. Pentane plus hexane, hexane, octane, nonane plus decane, gasolene and kerosene are shown to be insoluble at —18° and —10° and with varying proportions SO₂. With kerosene at —18°, from 33.3% to 98% SO₂ were used. The relative solubility of the liquid SO₂ in paraffins was determined ranging from an unmeasureable quantity at —18° to 1.8% at —10° for the low boiling-point members and increasing in solubility to 3.6% in the higher boiling kerosene oil. There was in no case an indication of paraffins appreciably dissolving in the liquid sulphur dioxide.

SOLUBILITY OF OLEFINS IN LIQUID SO₂

The solubility of olefins in liquid SO₂ is shown in Graph I. The behavior at —18 deg. and —10 deg. for 33.3 per cent and 66.7 per cent liquid SO₂ corresponds to that of the aromatics, namely, entire miscibility.

SOLUBILITY OF NAPHTHENES IN LIQUID SO₂

The solubility of naphthene hydrocarbons is shown in Graphs I and II. Edeleanu (loc.cit.) and Browery (loc.cit.) both state that naphthenes are entirely insoluble in liquid sulphur dioxide and after treatment are left with the paraffins. The present work, however, indicates that naphthenes vary in solubility from 0 to 100 per cent depending on the temperature and concentration of the liquid SO₂. Graph II shows the solubility of pure cyclohexane at temperatures of —18 deg., —10 deg., —7.5 deg. and —4.5 deg. C. and at

percentages SO₂ ranging from 45 to 91. Below 45 per cent SO₂, that is, nearly an equal volume, there is no solubility at —18 deg. C. and only 3 per cent at —4.5 deg. C. With about 70 per cent SO₂, however, the solubility shows a marked increase. The solubility also increases rapidly with temperature; with 89.4 per cent SO₂ the solubility is about 58 per cent at —18 deg. and 100 per cent at —4.5 deg. C. One marked peculiarity of the naphthene action with SO₂ is that as the concentration of SO₂ reached a point between 83 per cent and 87 per cent white crystals appeared in the oils, remaining upon addition of more SO₂.

TABLE III. SOLUBILITY OF NAPHTHENES IN LIQUID SULPHUR DIOXIDE

B.P. of Naphthenes Used	Temp. °C.	% SO₂ Used	% Naphthene Dissolved
175°–185°	—10	50.0	0.0
175°–185°	—10	67.0	0.0
175°–185°	—10	75.0	0.0
175°–185°	—10	80.0	0.0
175°–185°	—10	81.8	4.0
175°–185°	—10	83.3	6.0
175°–185°	—10	85.5*	13.0
175°–185°	—10	87.5	16.5
175°–185°	—10	88.5	23.0
75°C–155°C	—10	50.0	0.0
75°C–155°C	—10	67.0	0.0
75°C–155°C	—10	75.0	4.0
75°C–155°C	—10	80.0	8.0
75°C–155°C	—10	83.3*	14.0
75°C–155°C	—10	83.9	15.0
75°C–155°C	—10	85.5	23.0
75°C–155°C	—10	87.5	30.0
75°C–155°C	—10	88.5	37.0

* Crystals formed.

TABLE IV. SOLUBILITY OF NAPHTHENES AT VARYING TEMPERATURES

	—18° C.		—10° C.		— 0° C.	
	% SO₂	% Dissolved	% SO₂	% Dissolved	% SO₂	% Dissolved
155°–175°	50.0	0	50.0	0	50.0	0
155°–175°	66.7	0	66.7	0	66.7	0
155°–175°	75.0	0	75.0	0	75.0	0
155°–175°	80.0	0	80.4	2	80.0	2.0
155°–175°	83.0	2	81.8	7	81.5	8.0
155°–175°	84.4	5	84.1	9	83.1	11.0
155°–175°	86.9	5	86.5	12	84.9*	15.0
155°–175°	87.2*	6	87.3*	14	86.3	20.0
155°–175°	89.2	18	87.8	17	87.35	24.0
155°–175°	90.5	25	88.6	19	88.9	28.0
155°–175°			88.9	20	89.25	30.0
155°–175°	Remainder Dissolves		89.4	22	89.5	32.0
155°–175°	When Warmed		90.0	28	90.2	39.0

* At this conc. SO₂ a white crystalline solid appears in oil and remains.

This peculiarity of behavior together with the rather marked increase in solubility at about 70 per cent SO₂ seems to point to some compound between the SO₂ and

GRAPH 1.

GRAPH 2.
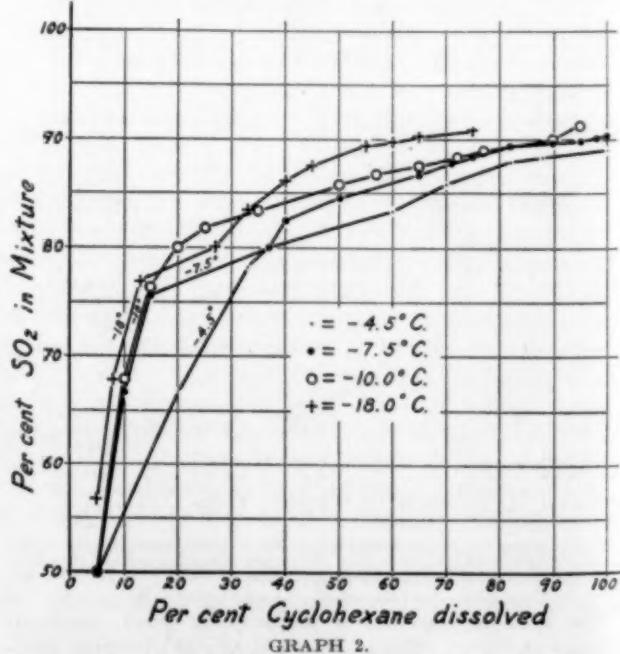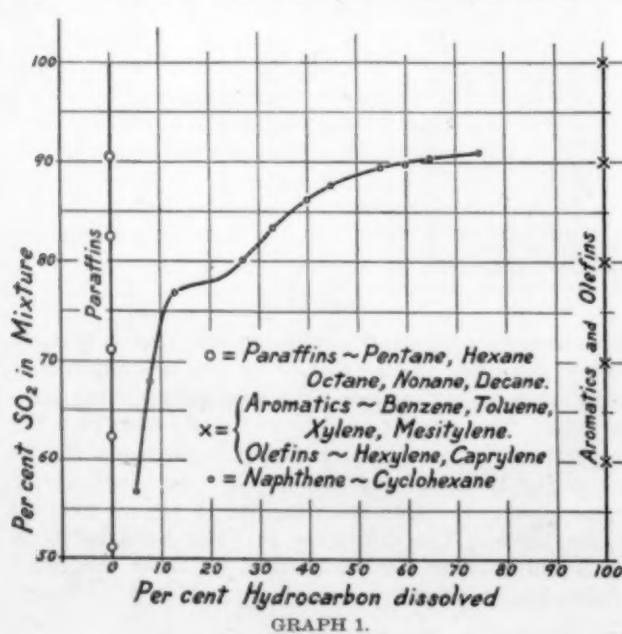
the naphthenes. The literature contains examples of compounds forming between liquid SO₂ and organic substances. For instance, De Bruin,[6] mixed isoprene with an equal volume liquid SO₂ and obtained a crystalline compound of the composition C₅H₈.SO₂ of definite melting point, 62.5 deg. Baumé and Pamfel[7] working with liquid SO₂ and methyl alcohol found indications of the formation of CH₃OH.SO₂ and 2CH₃OH.SO₂. The case in question does not seem to be plain solubility but probably formation of a compound which is stable only at low temperatures and in the presence of considerable SO₂. Further investigation on this point is being conducted.

The naphthenes of higher boiling-point (Tables III and IV) show a much smaller solubility than cyclohexane. The fraction 175 deg. — 185 deg. is insoluble up to 80 per cent. SO₂ but shows a marked increase from there on, giving a solubility of 23 per cent upon the addition of only 8.5 per cent more SO₂.

One of the difficult problems heretofore in oil work has been the determination of naphthenes in the presence of paraffins. The usual method has been merely a calculation based on the boiling point, index and specific gravity of the unvitratable oil;[8] while Kramer and Bottcher's method involves fractionation to within one or two degrees and carbon and hydrogen determinations of these fractions to estimate naphthenes present. These methods obviously are proximate at best, the second one involving considerable manipulation. The action of liquid sulphur dioxide therefore may prove a valuable aid not only in estimating napthenes in paraffins but separating them for further test. The application of this method to the separation of synthetic mixtures of naphthenes and paraffins is given later.

ACTION OF SULPHUR DIOXIDE ON SYNTHETIC MIXTURES

The work on synthetic mixtures is divided into six sections, as follows:

A.—Paraffin-Aromatic Mixtures.
B.—Naphthene-Aromatic Mixtures.
C.—Paraffin-Olefin Mixtures.
D.—Paraffin-Naphthene Mixtures.
E.—(a) Olefin-Naphthene Mixtures.
    (b) Olefin-Aromatic Mixtures.
F.—Paraffin-Aromatic-Olefin Mixtures.:

A.—Paraffin-Aromatic Mixtures

Benzene-Hexane, Table V.
Toluene-Octane, Table VI.
Toluene-Kerosene, Table VII.

Although the aromatic oils are entirely miscible with the solvent used, while paraffin oils are insoluble, the paraffin-aromatic mixture treated with the solvent presents many complexities. In the first place, the system aromatics-sulphur dioxide has a capacity for dissolving paraffins which sulphur dioxide alone has not. This is shown in the above tables by the increasing solubility of the paraffins as the percentage of aromatics in the mixture is increased. With 50 per cent benzene present, the paraffin-aromatic mixture is 100 per cent soluble. This is true also for the toluene-paraffin mixtures. The extraction of aromatics by sulphur dioxide is, therefore,

[6]Proc. K. Akad. Wetensch. Amsterdam, 17,585, 1914.
[7]Compt. Rend., 152,1095, 1911.
[8]Engler-Hofer, Das Erdöl, on Naphthenes.

TABLE V. SEPARATION OF PARAFFIN-AROMATIC MIXTURES

Benzene——————Specific Gravity, 0.880; Index of Refraction, 1.5014
Pentane and Hexane—Specific Gravity, 0.650; Index of Refraction, 1.3700

Temp. °C.	Mixture % Paraffin	% Benzine	% Mixture Used	% SO₂ Added	% of Oil Mixture Dissolved	Dissolved Index	% Benzine Calculated	Undissolved
—18	95.0	5.0	50.0	50.0	5.0	1.4860	88.3	1.3741
—18	90.0	10.0	50.0	50.0	15.0	1.4786	82.6	1.3753
—18	85.0	15.0	50.0	50.0	28.5	1.4705	76.5	1.3770
—18	80.0	20.0	50.0	50.0	32.5	1.4593	67.9	1.3814
—18	50.0	50.0	50.0	50.0	100.0	......	......	......

TABLE VI. PARAFFIN-AROMATIC MIXTURES

Toluene—Specific Gravity, 0.870; Index of Refraction 1.4982
Octane —Specific Gravity, 0.706; Index of Refraction, 1.3999

Temp. °C.	% Octane in Mixture	% Toluene in Mixture	% of Mixture Used	% SO₂ Used	% Oil Mixture Dissolved	Index of Undissolved Oil	Index of Dissolved Oil
—18	95.0	5.0	50.0	50.0	1.5	1.4002	1.4600
—18	90.0	10.0	50.0	50.0	5.0	1.4075	1.4694
—18	85.0	15.0	50.0	50.0	14.5	1.4040	**1.4792
—18	80.0	20.0	50.0	50.0	19.0	1.4018	1.4688
—18	75.0	25.0	50.0	50.0	27.0	1.4024	1.4554
—18	50.0	50.0	50.0	50.0	100.0	......	......
—18	50.0	50.0	30.0	70.0	92.5	......	......
—18	50.0	50.0	18.5	81.5	93.0	......	......
—18	50.0	50.0	15.2	84.8	100.0	......	......

** = 86.8% Toluene.

TABLE VII. PARAFFIN-AROMATIC MIXTURES

Kerosene—Specific Gravity, 0.779; Index of Refraction, 1.4277
Toluene —Specific Gravity, 0.870; Index of Refraction, 1.4982

Temp. °C.	% Kerosene in Mixture	% Toluene in Mixture	% of Mixture Used	% SO₂ Used	% Oil Mixture Dissolved	Index of Dissolved Oil	Index of Undissolved Oil
—18	90.0	10.0	50.0	50.0	5.5	1.4732	1.4311
—18	85.0	15.0	50.0	50.0	14.3	1.4794	1.4308
—18	80.0	20.0	50.0	50.0	19.0	1.4813	1.4302
—18	75.0	25.0	50.0	50.0	22.0	1.4789	1.4312
—18	95.0	5.0	54.0	46.0	2.5	......	......
—18	95.0	5.0	39.2	60.8	6.5	1.4659	1.4285
—18	95.0	5.0	33.3	66.7	10.0	......	......
—18	95.0	5.0	19.5	80.5	20.0	......	......
—18	95.0	5.0	19.0	81.0	20.0	......	......
—18	95.0	5.0	15.0	85.0	20.0	1.465	1.4782
—18	50.0	50.0	73.0	27.0	100.0	......	......
—18	50.0	50.0	59.4	40.6	74.5	......	......
—18	50.0	50.0	50.6	49.4	62.5	......	......
—18	50.0	50.0	41.7	58.3	62.3	......	......
—18	50.0	50.0	38.0	62.0	65.0	......	......
—18	50.0	50.0	29.1	70.9	68.7	......	......
—18	50.0	50.0	22.6	77.4	72.6	1.4715	1.4494

limited to mixtures containing below 50 per cent aromatics, and efficient extraction is possible only below 25 per cent aromatics. Table V shows that from a mixture containing only five per cent benzene, it is possible with one extraction to separate an oil of 88.3 per cent benzene content, using an equal volume of sulphur dioxide. The percentage of benzene content is calculated, in each case, from the index of refraction, using the formula

$$\frac{(m - p)100}{a - p} = \% \text{ aromatics}$$

where m = index of mixture;
    p = index of paraffins used;
    a = index of aromatics used.

As the percentage of benzene in the original mixture is increased, the solubility of the mixture rapidly increases, the bulk of the aromatics being extracted. With 15 per cent benzene in the mixture it is possible to separate nearly all the aromatics, the extraction representing 76.5 per cent benzene. Both the toluene and benzene mixtures show best extractions when the aromatics are present to an extent not exceeding 20 to 25 per cent. Certain natural petroleums which contain aromatics usually are under 15 per cent in aromatics content, and therefore lend themselves admirably to the sulphur dioxide extraction. This ideal percentage of about 15 per cent aromatics was used by Browery (loc.cit.) in extractions with sulphur dioxide and yielded

satisfactory results, especially when a number of extractions were made, using each time small quantities of the solvent.

In Table VI, a mixture containing 15 per cent toluene and 85 per cent octane yields an extraction equal to 14.5 per cent of the entire volume. The index of this extraction denotes 86.8 per cent toluene. This is a little better extraction than can be obtained from a kerosene-toluene mixture which under the same conditions yields a 73.3 per cent toluene in one extraction. By extracting a number of times with small quantities of the solvent, much purer aromatics may be separated.

The effect of extracting with various concentrations of the solvent, keeping the concentration of the mixed oils constant, led to interesting results which should receive discussion. Table VII shows that using a constant mixture of 95 per cent kerosene and 5 per cent toluene, and increasing the amount of sulphur dioxide added from 50 per cent to 85 per cent, the amount dissolved increased to a maximum of 20 per cent with 80.5 per cent solvent. Further addition of sulphur dioxide effected no further dissolving. A marked peculiarity in behavior, however, was noticed on 50 per cent mixtures of kerosene and toluene with increasing addition of solvent. With 27 per cent solvent the mixture was completely soluble. As the amount of solvent increased, less and less of the mixture dissolved until at 58.3 per cent solvent, a minimum solubility of 62.3 per cent of oil was reached. With further addition of solvent, the solubility increased. This peculiar behavior is also shown by the octane-toluene mixtures and is deemed sufficiently interesting to be shown graphically in Graph III. This retrograde solubility is evidence of the complexity of the aromatic-paraffin-sulphur dioxide system, a three-component system, for starting with a homogeneous system we pass to a heterogeneous system and finally to a homogeneous system again, merely by altering one concentration.

In Tables V, VI and VII, the purity of the dissolved and the undissolved oils can be ascertained by comparing their indices of refraction with the indices of

GRAPH 3.

the original oils as given under the heading of each table. For instance, in Table VI, the indices of the undissolved oils, in each case, are very close to the value for the pure octane, i.e., 1.3999, showing that virtually all of the aromatics have been removed .

B.—AROMATIC-NAPHTHENE MIXTURES

Benzene-Cyclohexane, Table VIII.
Xylene-Naphthenes, Table IX.

TABLE VIII. SEPARATION OF AROMATIC-NAPHTHENE MIXTURES
(Aromatic)—Benzene— Specific Gravity, 0.880; Refractive Index, 1.5014
(Naphthene)—Cyclohexane Specific Gravity, 0.780; Refractive Index, 1.4255

Temp. °C.	% Benzene in Mixture	% Cyclohexane in Mixture	% Mixture Used	% SO₂ added	% Oil Mixture Dissolved	Index of Dissolved Oil	Index of Undissolved Oil
−18	10.0	90.0	73.0	27.0	0.0	......	......
−18	10.0	90.0	60.0	40.0	5.0	1.4992	1.4258
−18	10.0	90.0	55.0	45.0	12.0	1.4965	1.4262
−18	10.0	90.0	50.0	50.0	22.5	1.4602	1.4261
−18	15.0	85.0	75.0	25.0	26.0	1.4616	1.4269
−18	15.0	85.0	67.0	33.0	28.0	1.4613	1.4271
−18	15.0	85.0	55.0	45.0	30.0	1.4608	1.4271
−18	15.0	85.0	50.0	50.0	32.5	1.4600	1.4276
−18	25.0	75.0	50.0	50.0	48.0	1.4608	1.4279
−18	25.0	75.0	25.0	75.0	62.0	1.4590	1.4274
−18	50.0	50.0	50.0	50.0	100.0	......	......
−18	50.0	50.0	45.0	55.0	100.0	......	......
−18	50.0	50.0	40.0	60.0	100.0	......	......

TABLE IX. SEPARATION OF AROMATIC-NAPHTHENE MIXTURES
Xylene—Refractive Index...................................... 1.4989
Naphthenes—Refractive Index.................................. 1.4345

Temp. °C.	% Xylenes in Mixture	% Naphthenes in Mixture	% of Mixture Used	% SO₂ added	% Mixture Dissolved	Index of Dissolved Oil	Index of Undissolved Oil
−18	5.0	95.0	50.0	50.0	3.2	1.4961	1.4398
−18	10.0	90.0	50.0	50.0	8.0	1.4918	1.4410
−18	15.0	85.0	50.0	50.0	13.8	1.4893	1.4411
−18	20.0	80.0	50.0	50.0	20.0	1.4879	1.4403
−18	25.0	75.0	50.0	50.0	30.0	1.4845	1.4415
−18	50.0	50.0	50.0	50.0	72.5	1.4722	1.4592
−18	60.0	40.0	50.0	50.0	100.0	......	......

In the experiments on the solubility of pure naphthenes, it was found that only a slight amount of this type hydrocarbon dissolved when less than 50 or 60 per cent of sulphur dioxide was used. It will be recalled that their solubility increased rapidly as the amount of solvent reached 75 to 80 per cent. It seemed probable, therefore, that aromatics which are completely miscible with sulphur dioxide, might be separated from the naphthenes if the percentage of solvent was kept low. The results given in Tables VIII and IX show this to be true. From a mixture containing only 10 per cent benzene and 90 per cent naphthenes it was possible to separate almost pure benzene, using equal volumes (50 per cent) of the solvent. The 15 per cent benzene mixtures also show a fairly good separation. But as the benzene content of the starting mixture increases, the sulphur dioxide-benzene mixture seems to form a solvent for the naphthenes, so that with 50 per cent aromatics present, the naphthenes are entirely miscible with 50 per cent sulphur dioxide. This is analogous to the solubility of paraffins in aromatics-sulphur dioxide mixtures. The xylene-naphthene mixtures (Table IX) show by comparison of the indices of refraction with the original oils, fairly satisfactory separations. In this case, as in the aromatic-paraffin separations, cleaner separations are possible with smaller amounts of xylene in the mixture. This is due to the solvent action of naphthenes of the xylene-sulphur dioxide complex, which is strengthened with increasing proportions of the aromatic. In no case in the naphthene-aromatic work was there noticed the peculiar retrograde solubility shown by the paraffin-aromatics.
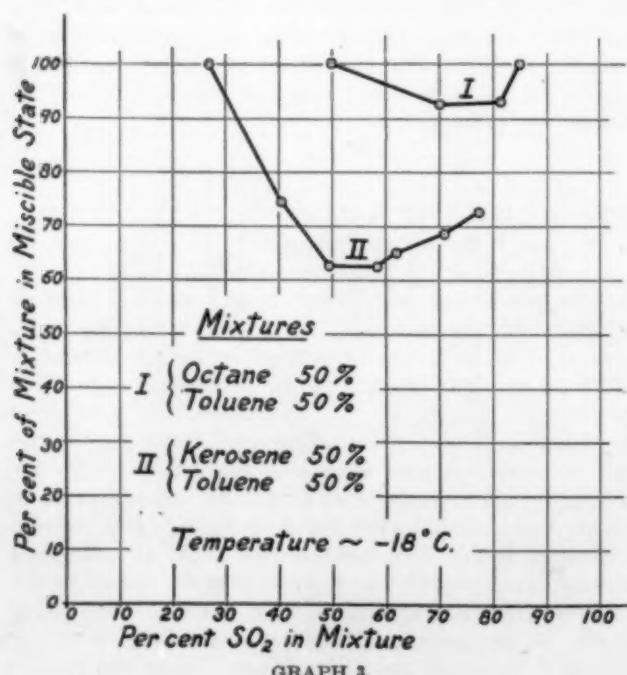
C.—PARAFFIN-OLEFIN MIXTURES

Hexane-Hexylene, Table X.

Pentane-Amylene, Table XI.

Pure olefins are entirely miscible with sulphur dioxide, while paraffins are insoluble. Tables X and XI show that olefins may be separated rather closely from mixtures which are not richer in olefins than about 20 to 25 per cent. In mixtures richer than 25 per cent the olefins and sulphur dioxide act as a solvent for the paraffins so that with 50 per cent olefins we have homogeneous systems formed. For paraffins containing under 20 per cent olefins, however, the indices of refraction show very good separations. The refining of gasolenes and kerosenes to free from unsaturated hydrocarbons is readily accomplished by liquid sulphur dioxide since in natural petroleums the percentage of olefins rarely is over 10 or 15 per cent, and usually not so high.

TABLE X. SEPARATION OF PARAFFIN-OLEFIN MIXTURES

(Paraffins)—Pentane and Hexane—Refractive Index, 1.3629
(Olefin)—Hexylene —Refractive Index, 1.3994

Temp. °C.	% Hexylene in Mixture	% Paraffins in Mixture	% Mixture Used	% SO₂ Used	% Oil Mixture Dissolved	Index of Dissolved Oil	Index of Undissolved Oil
—18	5.0	95.0	50.0	50.0	1.3	1.3978	1.3678
—18	10.0	90.0	50.0	50.0	5.0	1.3935	1.3689
—18	15.0	85.0	50.0	50.0	6.5	1.3918	1.3789
—18	20.0	80.0	50.0	50.0	7.5	1.3905	1.3791
—18	25.0	75.0	50.0	50.0	20.0	1.3873	1.3803
—18	50.0	50.0	50.0	50.0	100.0	......	......

TABLE XI. SEPARATION OF PARAFFIN-OLEFIN MIXTURES

(Paraffin)—Pentane—Index of Refraction 1.3629
(Olefin) —Amylene—Index of Refraction 1.3880

Temp. °C.	% Amylene in Mixture	% Pentane in Mixture	% Mixture Used	% SO₂ Used	% Oil Mixture Dissolved	Index of Dissolved Oil	Index of Undissolved Oil
—18	5.0	95.0	50.0	50.0	2.7	1.3875	1.3634
—18	10.0	90.0	50.0	50.0	6.6	1.3868	1.3650
—18	15.0	85.0	50.0	50.0	10.5	1.3821	1.3676
—18	20.0	80.0	50.0	50.0	14.2	1.3792	1.3690
—18	25.0	75.0	50.0	50.0	20.5	1.3774	1.3705
—18	50.0	50.0	50.0	50.0	100.0	......	......

D.—PARAFFIN-NAPHTHENE MIXTURES

Nonane-Cyclohexane, Table XII.

Gasolene-Naphthenes (75 deg. — 155 deg.), Table XIII.

Gasolene-Naphthenes (175 deg. — 200 deg.), Table XIV.

Paraffins (175 deg. — 200 deg.)-Naphthenes (175 deg. — 200 deg.), Table XV.

Although the literature[a] on sulphur dioxide refining of oils states that naphthenic hydrocarbons are as insoluble in sulphur dioxide as the paraffins and remain undissolved with them after the aromatics and unsaturateds are removed, the present work on individual naphthenes indicates that these hydrocarbons may be entirely dissolved, providing sufficient solvent is added. This solubility curve takes a sharp rise when about 85 per cent of the solvent is added, indicating the formation of a chemical complex. The crystals formed at about this concentration offer further evidence in support of this assumption.

Since this difference in solubility exists, the separation of naphthenes from paraffins was investigated, with a satisfactory degree of success as shown in Tables XII, XIII, XIV and XV.

[a]Cf. Edeleanu (loc. cit.) and Browery (loc. cit.)

Comparing, in these tables, the index of the dissolved and undissolved portions with the indices of the original oils, we find in every experiment considerable separation and in certain cases very close separation. It will be noticed that when only an equal quantity of solvent was added no separation occurred, but that the solubility of the naphthenes was marked when over 80 per cent solvent was used. Thus, in Table XII, when to a mixture of 15 per cent cyclohexane in 85 per cent paraffins, 86.7 per cent sulphur dioxide was added, a separation of 15 per cent oil took place. The index of this soluble portion was 1.4205 compared with 1.4255 for the pure cyclohexane, a very satisfactory separation. The other tables show equally good separations for mixtures containing up to 25 per cent naphthenes. Above this percentage separations are not as clean cut, the paraffins tending to dissolve in the naphthene-sulphur dioxide system.

TABLE XII. SEPARATION OF PARAFFIN-NAPHTHENE MIXTURES

(Paraffins) —Nonane + decane; Sp.Gr. = 0.730; Index of Refraction 1.4174
(Naphthene)—Cyclohexane; Sp.Gr. = 0.780; Index of Refraction 1.4255

Temp. °C.	% Paraffin in Mixture	% Naphthene in Mixture	% Mixture Used	% SO₂ Added	% Oil Mixture Dissolved	Index of Dissolved Oil	Index of Undissolved Oil
—18	85.0	15.0	50.0	50.0	0.0	......	......
—18	85.0	15.0	31.2	68.8	0.0	......	......
—18	85.0	15.0	24.4	75.6	0.0	......	......
—18	85.0	15.0	19.2	80.8	0.0	......	......
—18	85.0	15.0	18.2	81.8	2.0	1.4250	1.4189
—18	85.0	15.0	15.4	84.6	7.0	1.4247	1.4183
—18	85.0	15.0	13.3	86.7	15.0	1.4244	1.4185
—18	85.0	15.0	10.0	90.0	15.0	1.4237	1.4187

TABLE XIII. SEPARATION OF PARAFFIN-NAPHTHENE MIXTURES

Gasolene Specific Gravity = 0.721; Index of Ref. 1.4008
Naphthene (75°-155°) Specific Gravity = 0.784; Index of Ref. 1.4267

Temp. °C.	% Paraffins in Mixture	% Naphthenes in Mixture	% Mixture Used	% SO₂ Added	% Mixture Dissolved	Index of Dissolved	Index of Undissolved
—18	95.0	5.0	50.0	50.0	0	......	......
—18	90.0	10.0	50.0	50.0	0	......	......
—18	85.0	15.0	50.0	50.0	0	......	......
—18	80.0	20.0	50.0	50.0	0	......	......
—18	75.0	25.0	50.0	50.0	0	......	......
—18	50.0	50.0	50.0	50.0	0	......	......
—18	75.0	25.0	47.5	52.5	0	......	......
—18	75.0	25.0	38.0	62.0	2.5	1.4258	1.4012
—18	75.0	25.0	34.8	65.2	3.5	1.4251	1.4029
—18	75.0	25.0	27.6	72.4	12.5	1.4215	1.4038
—18	75.0	25.0	20.5	79.5	23.0	1.4189	1.4041
—18	75.0	25.0	17.8	82.2	25.0	1.4172	1.4058

TABLE XIV. SEPARATION OF PARAFFIN-NAPHTHENE MIXTURES

Gasolene—Index of Refraction...1.4187
Naphthenes—Index of Refraction...1.4460

Temp. °C.	% Naphthenes in Mixture	% Paraffins in Mixture	% Mixture Used	% SO₂ Added	% Mixture Dissolved	Index Dissolved Oil	Index Undissolved Oil
—18	5.0	95.0	15.0	85.0	2.5	1.4455	1.4188
—18	10.0	90.0	15.0	85.0	6.6	1.4442	1.4192
—18	15.0	85.0	15.0	85.0	10.0	1.4415	1.4199
—18	20.0	80.0	15.0	85.0	13.4	1.4395	1.4211
—18	25.0	75.0	15.0	85.0	19.2	1.4386	1.4222
—18	50.0	50.0	6.0	94.0	35.0	1.4322	1.4239

TABLE XV. PARAFFINS-NAPHTHENES MIXTURES

Paraffins B.P. = 175°-200°C; Sp.G. = 0.781; Index = 1.4277
Naphthenes B.P. = 175°-200°C; Sp.G. = 0.824; Index = 1.4460

Temp. °C	% Paraffins in Mixture	% Naphthenes in Mixture	SO₂ Used Twice Volume of Oil	% Dissolved Oil	Index	Undissolved Index
—15°	85	15		13	1.4450	1.4282

Table XIII gives the results of a run on 150 cc. of mixture containing 15 per cent of naphthenes boiling

from 175 deg. to 200 deg., and 85 per cent of paraffins of the same boiling point. In one treatment, using twice the volume of solvent as of oil, 13 per cent of the oil dissolved. The index of this portion showed almost pure naphthenes.

Heretofore there has been no method of separating naphthenic from paraffin hydrocarbons. The determination of such a mixture in the past involved fractionation to one or two degrees and analysis of the carbon and hydrogen content. Liquid sulphur dioxide, therefore, may prove a valuable aid in such a determination, particularly as the naphthenes are recovered and may be used for further physical and chemical tests. Moreover, since naphthenes have been regarded as the best lubricants of all hydrocarbons, the separation of these, almost pure, may prove of commercial value in the refining of such oils.

E.—(a) Olefin-Naphthene Mixtures, Table XVI
(b) Olefin-Aromatic Mixtures, Table XVII

TABLE XVI. SEPARATION OF OLEFIN—NAPHTHENE MIXTURES

Octylene—Index of Refraction................................. 1.4145
Naphthenes—Index of Refraction.............................. 1.4267

Temp. °C.	% Olefin in Mixture	% Naphthene in Mixture	% of Mixture Used	% SO₂ Used	% of Oil Mixture Dissolved	Index of Dissolved Oil	Index of Undissolved Oil
—18	10.0	90.0	50.0	50.0	8.5	1.4147	1.4263
—18	20.0	80.0	50.0	50.0	17.0	1.4156	1.4259
—18	50.0	50.0	50.0	50.0	46.0	1.4162	1.4250

TABLE XVII. OLEFIN-AROMATIC MIXTURES

Benzene—Index of Refraction...................................... 1.5014
Hexylene—Index of Refraction.................................... 1.3994

Temp. °C	% Olefin in Mixture	% Aromatic in Mixture	% Mixture Used	% SO₂ Added	% Oil Dissolved
—18	20.0	80.0	50.0	50.0	100.0
—18	50.0	50.0	50.0	50.0	100.0

(a) Olefin-Naphthene Mixtures. For this separation was used a mixture of octylene (index 1.4145) and naphthenes boiling between 75 deg. and 155 deg. (index 1.4267). The results are shown in Table XVI. Using a volume of solvent equal to the volume of oils, it was possible to make very close separations on mixtures containing as high as 50 per cent olefins. The separation of practically pure olefins from naphthenes is possible with sulphur dioxide, providing that not higher than 50 per cent of the solvent is used. This percentage of solvent must not be greatly increased since the naphthenes themselves become appreciably soluble with increasing amounts of sulphur dioxide.

(b) Olefin-Aromatic Mixtures. Olefins and aromatics are each entirely miscible with liquid sulphur dioxide, and, as would be expected, their mixtures in different proportions were entirely soluble. These runs are shown in Table XVII.

F.—Paraffin-Aromatic-Olefin Mixtures

Separation of Gasolene, Xylene, Octylene, Table XVIII.

Table XVIII gives the result of adding equal volumes of sulphur dioxide to gasolene containing varying proportions of xylene and the olefin octylene. The latter two, when present to an extent not exceeding 25 per cent of the volume of the oil, could be quite readily and almost completely removed as the refraction indices of the separated oils indicate. It is this separation which can be very usefully applied to the refining of American petroleums since the aromatics and olefins

TABLE XVIII.—PARAFFIN-AROMATIC-OLEFIN MIXTURES

	Sp. G.	Index
(Parffin)—Gasolene...................................	0.721	1.4008
(Aromatic)—Xylene....................................	0.880	1.4989
(Olefin)—Octylene.....................................	0.724	1.4145

Temp. °C	% Paraffin in Mixture	% Aromatic in Mixture	% Olefin in Mixture	% Mixture Used	% SO₂ Added	% Oil Dissolved	Index of Dissolved Oil	Index of Undissolved Oil
—18	95.0	3.3	1.7	50.0	50.0	4.0	1.4889	1.4010
—18	90.0	6.7	3.3	50.0	50.0	9.5	1.4868	1.4013
—18	85.0	10.0	5.0	50.0	50.0	12.0	1.4836	1.4065
—18	80.0	13.3	6.7	50.0	50.0	17.5	1.4818	1.4087
—18	75.0	16.7	8.3	50.0	50.0	31.5	1.4527	1.4157
—18	50.0	33.3	16.7	50.0	50.0	100.0	......	......

are considerably below the 25 per cent limit. Moreover, the olefins and aromatics are readily recovered from the sulphur dioxide, a fact which is in marked contrast with the present oil-refining losses due to the removal of unsaturateds with sulphuric acid.

As the percentage of aromatics and unsaturateds exceeded 25 per cent of the mixture, the solubility of the paraffins became more marked. With 50 per cent aromatics and olefins present, the mixture was entirely miscible with the solvent.

This separation was checked up on crude unwashed Pennsylvania gasolene and kerosene. In each case the sulphur dioxide dissolved more than was removed by the sulphonation for olefins and nitration treatment for aromatics. The index of the oil treated with sulphur dioxide showed much purer paraffin hydrocarbons remaining, while the dissolved olefins and aromatics were recovered.

Summary

1. The solubilities of a number of pure aromatics, pure paraffins, pure olefins and naphthenes in liquid sulphur dioxide have been determined for various concentrations.

2. Naphthenes, which the literature states are insoluble, may be completely dissolved in sufficient quantities of the solvent.

3. In order to investigate the utility of the liquid sulphur dioxide method for oil refining and also for analytical work, a number of separations were attempted on mixtures of the above types of hydrocarbons in various proportions. It has been found that within certain limiting concentrations,

    a—aromatics may be separated from paraffins or naphthenes

    b—olefins may be separated from paraffins or naphthenes

    c—aromatics and olefins together may be separated from paraffins or naphthenes

    d—naphthenes may be separated from paraffins.

4. The application of the liquid sulphur dioxide method to analytical work on oils is of importance since the separated unsaturateds or aromatics may be recovered and their identity proven by further physical tests. In sulphonation for olefins and nitration for aromatics these oils are lost. Moreover, naphthenes may be separated from paraffins within prescribed limits, a fact that will appeal to the oil analyst.

5. The application of the sulphur dioxide method to oil refining may prove of importance since the valuable aromatics and unsaturated hydrocarbons are recovered, the refined oil is purer than the acid method yields, and the sulphur dioxide may be applied and recovered in a continuous cycle.

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Standardization of Base-Metal Thermocouples*

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A FORM of furnace especially adapted to the rapid testing of a large number of couples consists of a tube of pure nickel or nickel-chromium alloy (chromel) clamped between two water-cooled terminals. A heavy current from a suitable transformer is passed through the tube, the tube itself serving as the heating element or resistor. For use with base-metal couples a porcelain insulating tube may be placed inside the metal tube or the base-metal couple may be wound with asbestos cord to electrically insulate it from the walls of the tube. In this case the standard couple, insulated in a non-porous porcelain tube, is placed with its hot junction as near as possible to the hot junction of the base-metal couple. Rare-metal couples may be standardized by taking proper precautions to prevent contamination by the metal vapors from the heating unit. The heating tube of this furnace is exposed to the air and no thermal insulating material is employed. A large concentric tube may be mounted around the heating tube to reduce the radiation loss, although this is not necessary. A furnace of this type may be heated very rapidly to any temperature up to 1100 deg. C. and it is possible to completely calibrate a couple at 5 or 6 different temperatures in a half hour.

CALIBRATION OF BASE-METAL COUPLES

It is difficult to secure equality of temperature between the hot junctions of two base-metal couples or between a base-metal and a rare-metal couple. One arrangement for precision calibration is to place the junction of the rare-metal couple in a small saw-cut made in the hot junction of the base-metal couple and pinch the jaws of the saw-cut until good thermal contact is secured. The rare-metal couple is protected by porcelain tubes to within a few millimeters of the hot junction and the end of the porcelain tube is sealed to the couple by a small amount of kaolin and water-glass cement. This prevents contamination of the rare-metal couple with the exception of the small length of 2 or 3 mm. which is necessarily exposed to the metal vapors. If the furnace is uniformly heated in this region, a small amount of contamination will not cause any error. The method however is not feasible for work on a large scale.

USE OF A MUFFLE FURNACE

Several base-metal couples and the standard rare-metal couples mounted in non-porous porcelain tubes are packed together as closely as possible and tied into a bundle with asbestos cord. The hot junctions are inserted into a length of very heavy iron pipe capped at one end, and the open end from which the couples protrude is tightly packed with asbestos wool. The iron tube and couples are mounted in the furnace

and the electromotive-force measurements are made as soon as temperature equilibrium is reached. If the muffle furnace is large enough, the iron tubes protecting the base-metal couples need not be removed. A satisfactory size of furnace measures 8 in. by 8 in. by 30 in. deep. Precision work is impossible in this method of calibration. Even when every precaution is taken to reduce temperature gradients, differences in temperature of 10 deg. or 20 deg. C. frequently will be found to exist between the different couples mounted side by side. However, this accuracy is sufficient for many industrial processes.

USE OF MOLTEN METAL BATH

The most satisfactory method for calibrating base-metal couples on a large scale is by use of a bath of molten metal. An iron pot about 12 in. diameter or larger and 15 in. deep is filled with tin covered with powdered graphite. This may be heated in a gas furnace or an electric furnace wound with nickel alloy such as nichrome or chromel. Into the tin bath dip about six iron tubes closed at the lower end and immersed to a depth of 12 in. The tubes are just large enough to permit easy insertion of the base-metal couple with its iron protecting tube. The standard couple is mounted in one of the six tubes and the base-metal couples are placed in the others. As soon as temperature equilibrium is reached the electromotive forces are measured, that of the standard couple giving the temperature of the bath. A large number of base-metal couples may be tested one after the other at this temperature and the process is then repeated at another temperature. The tin bath may be used satisfactorily in the range 300 deg. C. to 1000 deg. C. since tin is a metal of low volatility.

The method may be improved by operating the furnace and standard couple in connection with a temperature-control apparatus so that the temperature of the bath remains constant during a series of measurements. This advantage, however, is offset by the extra expense and complication of additional apparatus and in general is unnecessary. Data obtained by the above method are plotted, temperature versus electromotive force, for each couple, and a smooth curve drawn representing the calibration. For some types of base-metal couple the curve is slightly S-shaped showing small inflections near the critical points of the metals of which the couple is constructed. In precision work the calibration must be made at short temperature intervals over these critical regions to determine the exact form of the temp.-emf. curve.

SINGLE POINT CALIBRATION OR CHECK POINT

It is frequently desirable to check a base-metal couple at a single point. If the couple is reading electromotive forces say 2 per cent higher at this temperature than the usual electromotive force or that shown by the

original calibration data it is customary to assume that it reads 2 per cent high at all temperatures. This method of calibration at best is only approximate and experimentally it is frequently found that a couple reading 2 per cent high at 800 deg. C. indicates correctly at 1000 deg. C. However, single point calibrations are of value especially as a check upon the behavior of any particular couple.

A convenient standard temperature for this work is the melting or freezing point of sodium chloride (common salt), chemically pure. This material melts or freezes at 801 deg. C. The salt may be used in a nickel or duriron crucible heated in a gas or electric furnace. The base-metal couples are immersed several inches in the bath and melting or freezing point curves observed as discussed in a previous article.[1] If the salt has not been previously fused, it must be melted the first time with a cover on the crucible as the imprisoned water in the salt crystals will cause the salt to sputter out badly. After the first melt, however, there will be no trouble in the use of this material. Molten salt reacts somewhat with most base-metal couples but the reaction is so slow that the couple will not be injured. The Bureau has not found any serious change in melting point resulting from heating the salt in contact with iron for several hours.

CALIBRATION OF THERMOCOUPLES WITH MILLIVOLTMETER OR INDICATING INSTRUMENT

When a thermocouple in a furnace is connected to a millivoltmeter, the electromotive force of the couple causes a current to flow around the circuit, which, in accordance with Ohm's law is equal to e/R where e is the electromotive force developed by the couple and R the total resistance of the circuit. The deflection of the pointer of the millivoltmeter is aproximately proportional to this current. Thus if the temperature of the furnace remains constant e is constant but the deflection of the instrument will be altered by changes in the resistance R. Hence any variation in R which produces a change in the reading of the instrument would be interpreted as a change in the temperature of the furnace although actually this is constant. The total resistance of the circuit may be divided into three parts, R_g the resistance of the millivoltmeter, R_L the resistance of the line, and R_c the resistance of the couple. If these resistances are properly proportioned the effect upon the reading of the indicator of any changes in the resistance R likely to occur can be reduced to practically zero. This condition is realized when R_g, the resistance of the galvanometer, is sufficiently high compared with $R_c + R_L$, the resistance of the external circuit. Suppose that the indicator has an electromotive force scale graduated to read the potential difference at its terminals. The relation between the reading of the instrument e_o and the true electromotive force e of the couple to which it is connected is given by the following equation:

$$e_o = \frac{R_g}{R_g + R_c + R_L} e$$

Thus if R_g is very large compared to $R_c + R_L$ the ratio $R_g / (R_g + R_c + R_L)$ is practically 1 and the reading of the galvanometer gives the true electromotive force of the couple.

[1]This journal, Apr. 1, 1918, p. 343.

Robust indicators are now obtainable having a resistance of 300 to 1200 ohms. As a particular example of the behavior of such an instrument, values of the factors occurring in the above equation will be considered for an actual thermocouple installation.

Galvanometer resistance $= R_g = 300$ ohms
Couple resistance $= R_c = 1$ ohms
Line resistance $= R_L = 1$ ohms

Whence

$$e_o = \frac{R_g}{R_g + R_c + R_L} e = \frac{300}{300 + 1 + 1} e = 0.993e$$

Thus, if the galvanometer is graduated to read potential differences at its terminals, the reading of the instrument gives the true electromotive force of the couple to within 0.7 per cent.

The construction of an indicator having a resistance of 300 ohms or more and having the necessary characteristics of robustness, portability, constancy in calibration, etc., is somewhat difficult. For this reason many manufacturers have secured these latter characteristics at a sacrifice of the desirable feature of high resistance. Instruments having a resistance of 10 ohms or less are in extensive use. Suppose a galvanometer, 10 ohms in resistance, calibrated to read potential differences at its terminals, is used in the circuit described above.

$$e = \frac{R_g}{R_g + R_c + R_L} e = \frac{10}{10 + 1 + 1} = 0.83e$$

Thus, if the galvanometer is graduated to read potential differences at its terminals, the electromotive force indicated by the instrument would be 17 per cent less than the true electromotive force of the couple. Such large errors are compensated for by arbitrarily graduating the scale to read the electromotive force of the couple when the resistance of the couple and line has a certain fixed value, in the above example 2 ohms. The instrument will accordingly read correctly for this external resistance but will read in error if the external resistance is altered. Bad contacts, deterioration of the couple from oxidation, change in depth of immersion, temperature coefficient of the copper lead wires, etc., may at any time alter the resistance of the external circuit. Let us compare the behavior of the 300-ohm instrument and the 10-ohm instrument, assuming both instruments are compensatingly graduated to read correctly for an external resistance of 2 ohms, when for one of the several reasons cited above the external resistance is increased by 1 ohm.

If the galvanometer were graduated to read potential differences at its terminals the relation between its reading e_o and the true electromotice force of the couple e would be given by the equation above. The instrument may be compensated so that its new reading, say e_o' is correct for some definite value of the external resistance. Inverting the former equation and putting $R_c + R_L + R'$:

$$e = \frac{R_g + R'}{R_g} e_o$$

It the compensated calibration is correct when $R' = R_o'$, then

$$e_o' = \frac{R_g + R_o'}{R_g} e_o$$

The per cent error in the reading e_o' due to a change

in R^1 is obtained by differentiating the following equation:

$$e_o{}^1 = \frac{R_g + R^1}{R_g} e_o$$

where R^1 is now a variable.

Per cent error in reading for change in R^1 of 1 ohm

$$= \frac{100 d e_o{}^1}{e_o{}^1} = \frac{100 d R^1}{R_g} \frac{e_o}{e_o{}^1} = \frac{100 d R^1}{R_g + R_o{}^1} = \frac{100(1)}{300 + 2} =$$

0.33% for 300 ohm indicator ⇔ about 3° at 1000° C. and $\frac{100(1)}{10 + 2} = 8.3\%$ for 10 ohm indicator ⇔ about 80° at 1000° C.

Thus when both instruments read correctly for an external resistance of 2 ohms, if the external resistance is increased by 1 ohm, the low resistance indicator is in error by 8.3 per cent while the high resistance instrument still reads practically correct. Considerations such as the above emphasize the importance of using a galvanometer having a resistance of 300 ohms or more. In actual operation the line resistance may change by several ohms on account of bad contacts and deterioration of the thermocouple.

The varying factor of line resistance has proven a strong argument in favor of a potentiometric method of measuring thermocouple electromotive force. A number of instruments based upon this principle are available. Besides the portable and laboratory types of potentiometer made by Leeds and Northrup there are special potentiometric galvanometer systems such as the pyrovolter made by the Pyrolectric Instrument Company, the Brown Heat Meter made by the Brown Instrument Company, and the Alladin made by Wilson-Maeulen. The high resistance galvanometer, however, is accurate enough for most purposes and possesses the advantages that it is less costly than the above instruments and that it indicates temperature continuously with no preliminary adjustments, while potentiometer installations require zero adjustments or balances on the standard cell, and except in the recording and deflecting potentiometers, a dial must be moved to obtain a setting.

Usually indicators are graduated to read temperature directly and do not have an electromotive-force scale. In this case they must be used with the type of couple for which the scale was designed. If the instrument has a resistance of more than 100 times the resistance of the external circuit no particular attention need be given to slight deviation from the prescribed resistance of the couple. The temp.-emf. relation of the couple for which the scale of the instrument is designed can be secured from the maker or can be determined in the laboratory by calibrating one of the couples as previously described.[*] The temp.-emf. relation can be also obtained directly from the temperature scale of the indicator by measuring with a potentiometer the potential drop across the terminals of the indicator when sufficient current is flowing through it to deflect the pointer to various scale readings. The reading of the potentiometer is equal to the emf. of the couple corresponding to a hot junction temperature given by the scale reading of the indicator and a cold junction temperature given by the reading of the indicator on open circuit. The various couples to be used with this in-

[*] This journal Apr. 1, 1918, p. 343.

strument may be calibrated in the laboratory by use of a potentiometer. If the temp.-emf. relation of each couple agrees closely with that of the standard temp.-emf. curves, the couples are satisfactory to use with this indicator without applying corrections.

Suppose one particular couple develops 30 millivolts at 1000 deg. C. while the standard reference couple for which the instrument was calibrated develops 30 millivolts at a temperature of 1030 deg. C. The first couple will accordingly read too high by 30 deg. C. when corrected to the indicator. Proceeding in this manner a correction table can be prepared for each couple showing a temp.-emf. relation much different from that of the reference couple. It is of course possible to calibrate in the laboratory the couple and high resistance indicator as a unit. This, however, is not always convenient, especially if the indicator is of the wall type or is in constant use.

The calibration of couples for use with an indicator of low resistance can be made in the manner described above or the couple and indicator with lead wires of the same resistance as that used in the permanent installation may be calibrated as a unit. In the first method great care must be taken to see that the line resistance of the finally installed couple is correct. Manufacturers obtain the correct resistance by the use of a coil of resistance wire in series with the couple and mounted in the head of the couple. By properly adjusting the extra resistance slight deviations in the temp.-emf. relation for any particular couple from that of the reference couple for which the scale of the indicator was designed, may be partially corrected for. It is scarcely advisable for the industrial plant to make adjustments of this character. If low-resistance indicators are employed it is probably better to purchase of the manufacturer couples adjusted for a specified line resistance and for the particular indicator.

In the use of low-resistance indicators the resistance of the line and couple should be frequently checked. The resistance may be measured by means of a "test set" or portable Wheatstone bridge. Obtain a setting for resistance in the usual manner, then reverse the + and — terminals of the line and obtain a second setting. The mean of the two resistances gives the correct resistance of the circuit. The two settings will be different because of the electromotive force developed by the couple. Another method of measuring the resistance of a couple while hot, is given in Bureau of Standards Scientific Paper No. 250, page 147 .

CHECKING THERMOCOUPLES IN FIXED INSTALLATIONS

It is frequently desirable to check the readings of a thermocouple without removing it from the furnace in which it is installed. Tests of this nature are of extreme importance in the technical industries. They are also difficult to perform with precision and the precision which is obtainable in a laboratory test can not be expected in tests of this nature. However, an ordinary calibration, in the laboratory, of a base-metal couple which has been in use in a fixed installation for some time, while furnishing results apparently of high precision, does not necessarily hold when the couple is returned to its original installation. This is on account of the heterogeneity developed in a base-metal couple after prolonged heating.

The presence of heterogeneity could be detected by a homogeneity test but such tests on a large scale are not worth while for base-metal couples and moreover do not show how to correct the readings satisfactorily. Such a test would simply indicate that the couple should be thrown away whereas in its permanent installation it still has a useful life. The throwing away of base-metal couples in a fixed installation as soon as heterogeneity sets up would be a very costly and unnecessary procedure except in the comparatively rare cases where the highest possible accuracy is required. The degree of heterogeneity developed depends upon the type of installation, depth of immersion, location and character of temperature gradient, etc. These quantities are fairly definite and fixed for any particular installation. If, however, the couple is removed from the installation and calibrated in the laboratory these quantities are altered and the conditions under which the couple is actually operating can not be reproduced. The calibration in the laboratory may give results quite different from the calibration which would be obtained if it were possible to duplicate exactly all the physical characteristics of the permanent installation. Hence it is evident that if non-homogeneous couples are ever to be used, it is important that they be calibrated or checked in their fixed installation.

The exact method of procedure depends upon the type of installation. A standard checking couple is employed complete with a high-resistance galvanometer or portable potentiometer. The hot junction of the checking couple is placed as closely as possible to the hot junction of the couple under test and the readings of the two couples compared. The main objection to the method is the difficulty in getting the two hot junctions together. One method is to drill a hole in the furnace at the side of each couple permanently installed large enough to permit insertion of the checking couple. The hole is kept plugged except when comparison tests are being made. The checking couple is immersed in the furnace through this hole to the same depth as the couple under test. The hole should be located as close to the permanently installed couple as possible.

In many installations the base-metal couple and protecting tube are mounted inside another protecting tube of iron, fire clay, carborundum, or some other refractory which is permanently cemented or fastened into the furnace wall. Frequently there is room to insert a small test couple in this outer tube along side of the fixed couple. A third method, much less satisfactory, is to wait until the furnace has reached a fairly constant temperature and make observations with the couple under test, then remove this couple from the furnace and insert to the same depth the checking couple.

If desired, comparisons can be made preferably by either the first or second method at several temperatures and a curve may be obtained for each permanently installed couple showing the corrections necessary to apply to its readings.

It may be argued that this method of checking couples is unsatisfactory because in most furnaces used in industrial processes large temperature gradients exist and there is no certainty that the standard couple is at the same temperature as the couple under test. This objection, however, is not serious because if temperature gradients do exist, in the furnace, of such a magnitude as to cause much difference in temperature between two similarly mounted thermocouples, located closely together, the accuracy required by the measuring instruments need not be great, and the reading of the standard couple can be accepted for the standardization of fixed couple just as satisfactorily as if the true temperature of the fixed couple were known. If temperature gradients exist of such a magnitude that two correctly calibrated couples similarly mounted closely together read say 20 deg. C. apart, it may be certain that neither couple is registering the temperature of material within the furnace to this degree of accuracy.

DEPTH OF IMMERSION OF THERMOCOUPLE

Thermocouples immersed in furnaces of the various industrial types must be carefully protected. Heavy iron tubes and frequently larger auxiliary protecting tubes of various materials are employed. The thermocouple calibrated in the laboratory will give the temperature of the hot junction when installed in the protecting tubes but there is no certainty that this temperature is that of the furnace. Conduction along the protecting tubes may be so great that the temperature of the couple is far below that of the furnace. Conduction losses affecting the temperature of the hot junction may be reduced and even eliminated by using a sufficient depth of immersion but it is not always possible to do this and it is difficult to determine when the depth of immersion is sufficient. For example, an immersion of 5 cm. might be satisfactory for one type of furnace, or for a molten bath, and 30 cm. insufficient for a certain muffle furnace.

Each particular case requires special consideration. The general practice is to use as deep immersion as is conveniently possible and trust that this is satisfactory. Two methods may be suggested for investigating the question but neither one is very conclusive. First, remove the couple alone from the fixed installation leaving all protecting tubes in place. If it is impossible to remove the iron tube from the couple use a similar tube in the fixed installation without the couple. Explore the temperature inside the protecting tube with an unprotected couple. If the temperature for several centimeters along the axis of the tube at the inner end is practically uniform, the depth of immersion is satisfactory. If, however, the temperature falls rapidly in this region the immersion is not deep enough. Second, the couple previously standardized is mounted complete in the fixed installation and compared with another checking couple mounted as previously discussed. The checking couple must have a small cross section and must be used either unprotected or protected by an extremely thin tube in order to minimize the loss of heat by conduction. The hot junctions of this couple and of the couple under test are brought closely together but not in contact. The checking couple should indicate a temperature more nearly that of the furnace than the temperature observed with the fixed couple. If the temperature difference between the two couples is large a greater depth of immersion should be employed. These methods are complicated by local variations in the temperature of the furnace but checks of this nature, although somewhat unsatisfactory, are better than no checks at all.

In an ordinary uncompensated thermocouple the

electromotive force developed depends upon the temperature of the cold junctions as well as upon the temperature of the hot junction. For some base-metal couples, having a linear relation between temperature and electromotive force, the electromotive force is proportional to the difference in temperatures of the hot and cold junctions. With such couples a change of 10 deg. C. in the temperature of the cold junctions, unless corrected for, would result in an error of 10 deg. C. in the temperatures indicated by the couples. Convenient methods for obtaining these corrections where the couple is used with the cold junctions at a temperature different from that for which it was calibrated are discussed in Bureau of Standards Scientific Paper No. 202. The following rules may be observed:

If a thermocouple has been calibrated with cold junctions at 0 deg. C. and is used with the cold junctions at t_a deg. C. add to observed electromotive force the value of the electromotive force developed when the hot junction is at t_a deg. C. and the cold junctions are at 0 deg. C. The original calibration then applies.

The corrections may be expressed in terms of degrees as follows: If a thermocouple has been calibrated with the cold junctions at 0 deg. C. and is used with the cold junctions at t_a deg. C., add to the observed temperature the quantity $F \times t_a$ deg. C., where F is a factor depending upon the type of couple employed and upon the temperature of the hot junction. The value of F varies from 1.5 to 0.3 for base-metal couples but for rough work it may be assumed equal to 1.0. The correct values may be obtained by the method described in the paper referred to above. For a platinum, platinum-rhodium couple F has the values given in the following table:

Platinum, Platinum-Rhodium Couple.
Calibrated at Cold Junction = 0°C.

Temperature of Hot Junction	F.
400°C.	0.61
800	0.54
1,200	0.47
1,400	0.45

A convenient method for applying these corrections is to set the indicator or galvanometer on open circuit to read the cold junction temperature. When this is done the above corrections are taken care of automatically, so long as the cold junctions remain at this temperature. Some types of indicators, especially the portable potentiometers, have a special adjusting dial for thus correcting for the cold junction temperatures. Bureau of Standards Scientific Paper No. 202 describes the method of correcting when the couple has been calibrated with a cold junction temperature of t_1 deg. C. or t_1 deg. F. and is used with a cold junction temperature of t_2 deg. C. or t_2 deg. F.

The importance of the control of the cold junction temperature is evident from the above discussion. Various devices are used to this purpose. The cold junction may be buried 8 or 10 ft. under ground at which depth the variations in temperature are scarcely ever more than 5 deg. C. throughout the year. The cold junctions may be maintained at 0 deg. C. by the use of ice boxes as discussed in a previous article (Apr. 1, 1918), although this method is not practical for a large industrial installation. Another method is to water-jacket the head of the couple allowing a small stream of water from the water main to flow through the jacket. Still another method in use is to lead wires of the same material as the couple from the couple to a cold junction box the temperature of which is thermostatically controlled. In all of these methods the couples are calibrated for the proper cold junction temperature.

In order to avoid the necessity of controlling the temperature of the cold junction near a furnace where the variations in room temperature are extreme, several methods of automatic compensation are in extensive use, such as balancing the decrease in electromotive force caused by an increase in the temperature of the cold junction by an external electromotive force from a battery. In this case an electrical circuit arranged in the form of a Wheatstone bridge is employed. Another method is the use, in the head of the couple, of a shunt and a series resistance, the latter having a zero temperature coefficient. Both of the methods give only partial compensation but by proper adjustment the compensation is accurate enough for most industrial work. The former method is usually effective over a much wider range of hot junction temperatures than the latter, which has its principal application for work in the neighborhood of the temperature for which it is arranged to give best compensation. In this temperature range the method is more desirable than the Wheatstone bridge method because no outside battery is required. Furthermore, in the latter method the degree of compensation depends upon the condition of the battery so that some attention is required to see that the battery is never run down.

A very simple method which is inexpensive, accurate, and convenient is the use of compensation lead wires from the couple to the indicator. Frequently the indicator or recorder is located in a room, at some distance from the furnace, where the temperature does not vary seriously. By means of the compensating leads the cold junction is moved from the head of the couple to this room and hence can be maintained at a fairly constant temperature. In the case of the base-metal couple the leads may be of the same material as the couple. The cost of platinum prevents such practice for rare-metal couples. However, inexpensive lead wires of copper and an alloy of copper-nickel are now available for use with the platinum, platinum-rhodium couple. Lead wires of this type have been tested at the Bureau of Standards and found to be very satisfactory, in fact the compensation is closer than 5 deg. C. for a variation in temperature of the couple-lead wire junctions of 200 deg. C. or more. Compensating lead wires for either base-metal or rare-metal couples may be carried from the couple to a cold junction box or to a pipe buried in the ground at some distance from the furnace. In this manner practically perfect control of the cold junction temperature is obtained.

METHOD OF MAKING THERMOCOUPLE JUNCTIONS

The hot junction of a thermocouple should be made by soldering or fusing the two metals. Silver solder is useful at temperatures below 900 deg. C. or gold below 100 deg. C., but in general the best type of junction is made by fusion. The junction of a rare-metal couple may be made by use of a small oxygen illuminating-gas flame. Acetylene is not desirable. Special blast lamps suitable for this work are obtainable. The flame should be small, possibly 4 cm. long, the tip of

the lamp having an opening of from 0.5 to 1 mm. The junction should be fused into a ball about 1 mm. in diameter.

Another convenient method of fusing the junction is by use of an electric arc. One of the couple wires is connected to the positive terminal of the 110 volt d.c. main and the negative terminal is connected through a resistance to a graphite pencil having an insulating handle. The graphite should be about 5 or 6 mm. in diameter and should be sharpened to a point. For a couple of 0.6-mm. wire, a resistance of 30 to 40 ohms is used. Touch together the ends of the two wires of the couple and then bring the point of the graphite pencil into contact with the junction. As soon as an arc is formed draw the pencil away. With a little practice excellent joints can be made in this manner.

This method is also good for repairing broken couples. In this case the junction should be made as nearly as possible of the same size as the wire itself.

Large base-metal couples may be fused either by an electric arc or oxygen-gas torch. It is frequently the practice to twist the two wires as shown in Fig. 1 for a few turns as this possibly gives greater mechanical strength. Before fusing, the junction of the couple is coated thoroughly with borax. This is done by heating the ends of the two wires to a dull red heat and then dipping into the powdered borax. The borax adhering to the wire is then melted and the process continued until a heavy coating of the fused transparent borax is obtained. The couple may be mounted horizontally or suspended with the junction down. The arc or oxygen-gas flame is allowed to play upon the junction until the metal fuses into a neat bead. If sufficient borax is used the weld will show no signs of oxidation. The arc employed for this work is of the ordinary type consisting of two carbons, although for small couples the form of arc described above may be used.

No flux should be employed when fusing rare-metal couples.

Do not allow borax to come in contact with the porcelain lining of a furnace or with porcelain tubes. What borax remains on a base-metal couple may be removed if desired by dipping the junction while hot into water. The borax glass will then crack away. In making thermocouple junctions dark glasses should be worn in order that the work may be watched closely. It is also essential that the glasses absorb the ultra-

violet light which may cause severe burns and injure the eyes. Special goggles for this type of work are advertised in the trade journals.

CONSTRUCTION OF BASE-METAL COUPLES

A company using large numbers of base-metal couples can profitably construct them from wire furnished by the manufacturer instead of purchasing completely mounted thermocouples. For temperatures up to about 900 deg. C., iron versus constantan is suitable. For temperatures up to 1100 deg. C. special-patented alloys are obtainable such as chromel versus alumel. Wire for the construction of the above couples may be purchased in coils of various gages, (usually No. 6 or No. 8) and all couples made from any two coils will have very nearly the same calibration if special attention has been given by the manufacturer to the securing of homogeneous material. Wire for this purpose is advertised in the trade journals. To make a couple, cut off the desired length for each wire and fuse the junction as described above. The two wires are insulated by fire clay or porcelain insulating tubes and are then mounted in a steel or other type of protecting tube. For certain types of work thermocouple wire insulated with asbestos is useful. Wire may be procured insulated in this manner, or the insulation can be put on in the laboratory. There are two methods of doing this, one by the use of asbestos sleeving and the other by use of asbestos cord. Samples of these materials can be secured from dealers in asbestos goods. The cord is wound back and forth across the two wires in a figure 8. After the asbestos is in place it is good practice to fill the spacing between turns with a refractory cement such as ground alundum and water glass. Several pyrometer manufacturers sell cements already mixed for this purpose. Couples protected in this manner can be used for many processes without the outside iron protecting case.

MAINTAINING LABORATORY RECORDS

One of the most serious faults of an industrial laboratory is the failure to maintain satisfactory records. All calibration data, operation, costs, etc., should be recorded and filed for ready reference. Companies using several hundred or thousand couples per year should be able to state definitely whether iron-constantan couples will serve their purpose as well as the more expensive nickel-alloy couples. For any particular process, will the longer life of the more expensive base-metal couple justify its installation for temperatures around say 900 deg. C.? For operation at 1100 deg. C. will the longer life of the still more expensive platinum couple justify its installation? A couple which is used at temperatures high enough to seriously shorten its life is liable at any time to develop inhomogeneity affecting its calibration. Is this question of accuracy of sufficient importance for any particular process to justify equipping with more expensive couples? What is the life of the various couples used at different temperatures expressed in hours per dollar of cost?

Many types of protecting tubes for base-metal couples are available such as fire clay, carborundum, duriron, nichrome. and steel. What is the most economical tube to use reckoned on a basis of life in hours per
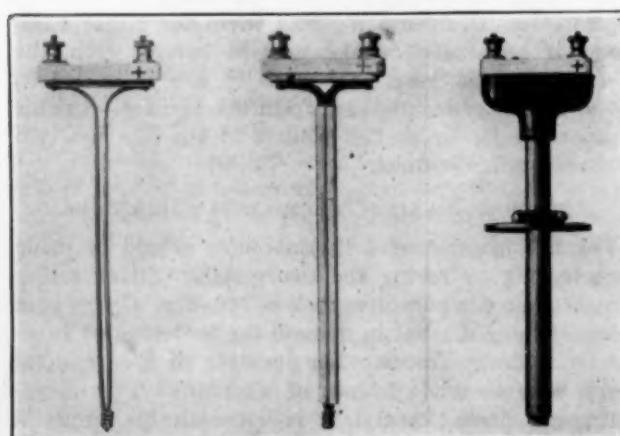

FIG. 1. TYPICAL FORM OF BASE METAL COUPLES. NOTE THE TWISTED WIRES AT WELDER JUNCTION.

dollar? What depth of immersion gives the most satisfactory results for any particular type of installation?

Fused quartz or silica tubes for rare-metal couples do not break as easily as porcelain when subjected to changes in temperature. On the other hand, quartz is not very satisfactory above 1100 deg. C. Which type of protecting tube is found to be more satisfactory for any process in question? Is the factor of variable lead resistance and change in resistance of the couple upon deterioration of sufficient importance to justify a potentiometric installation for any particular process? What is the best method of checking couples in a certain fixed installation? What method is found by experience to be the most satisfactory for controlling the temperature of the cold junctions of the thermocouples?

Are they records made by the recorders, of real service, or are they simply filed away and no attempt made to correlate the data with properties of the finished product? Do the records show that the heating of the furnace has followed specifications and if not what is the best method of remedying this difficulty in the future? Should a method of automatic temperature control or signaling be adopted? Would a bonus system, awarding the furnace operator a certain increase in wages when the temperature of a furnace is maintained within prescribed limits, prove a profitable solution of the difficulty? Would an installation of optical pyrometers serve more satisfactorily than thermocouples for a certain process? Is the disadvantage that optical pyrometers cannot be made recording offset by a decrease in cost of maintenance of thermocouples, at extreme temperatures? Would it be economical to hire a man whose sole work would be to observe, with an optical pyrometer, the temperatures of several furnaces? Or should a recording radiation pyrometer be employed?

Many of the above questions have been briefly considered in the present discussion but the most satisfactory answer to these and similar questions can be obtained from a systematic study of all records and data. The suggestions for efficiency should not be pushed to an extreme. It is better to err on the side of extravagance than economy in operating a pyrometer installation. The primary object should be to have a perfect working system of temperature control. However, expenses which the records show to be unnecessary should be curtailed.

Besides aiding in the establishment of an efficient system of temperature control the records are of extreme value for investigational work. In this field the pyrometer engineer must coöperate with the metallurgist and chemist. These latter, for example, find that the product which was heat treated on a certain date possesses certain properties which are especially valuable. It is desired to exactly duplicate the special heat treatment or to possibly alter the method slightly with the idea of producing still further improvements in the product. Investigational work of this character and even more specialized research may be carried on simultaneously with the routine work. The metallurgist, chemist, pyrometer engineer, and all concerned, including the operators of the furnace, will develop increased interest in their work because the spirit of research creates enthusiasm.

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Bibliography on the Physical Properties of Copper

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IN THE series of four articles on the physical properties of copper and the factors by which they are affected, completed in the last issue of *Metallurgical & Chemical Engineering*, reference was frequently made to original sources of information. Those sources are here presented as a bibliography of the subject. The segregation of references by topics will be found specially useful and convenient.

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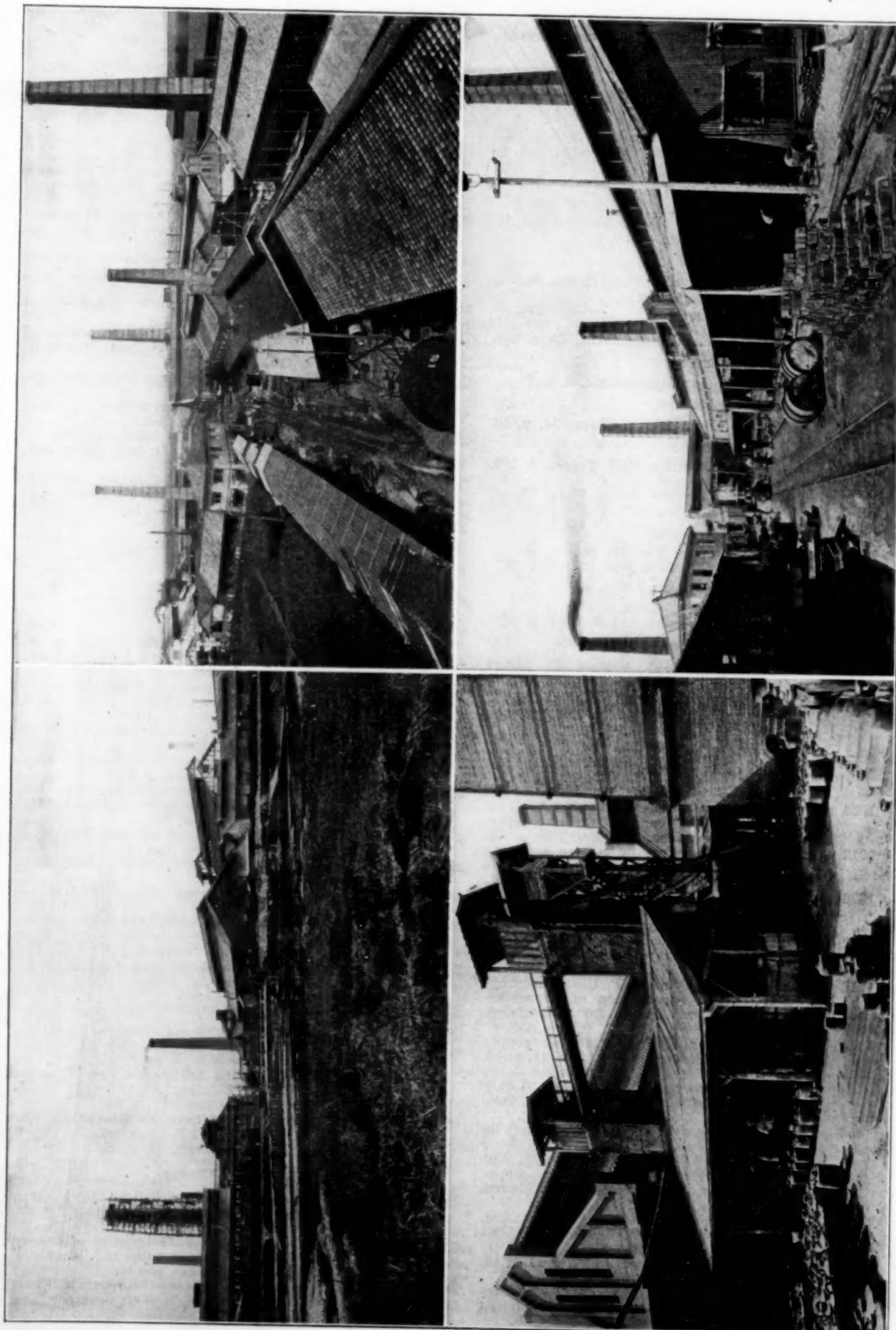
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Chemistry in Japan

DR. ALCAN HIRSCH of New York, consulting chemical engineer to the Japan Dyestuff Mfg. Co., Ltd., and consulting chemist to the pharmaceutical and drug establishment of the Sankyo Co., returned March 19th from Japan. In an interview with Dr. Hirsch by a member of our staff, he said that the coal-tar dyestuff industry in Japan was getting well established and flourishing. The Japan Dyestuff Co., which he serves, is that which was organized under government auspices in 1916, and is much the largest. The second in capacity is the Mitsui Co., which addresses itself to making anthracene products, and there are about ten other small concerns making a limited number of colors.

Among the products of the Japan Dyestuff concern are, as intermediates, aniline, phenol, naphthylamines, toluidines, nitrophenol, tolidine, methyl-anilines, naphthols, H-acid, dianisidine and Micheler's ketone. Among the colors produced on a commercial scale and on the market are benzo fast red A, congo red, benzo purpurine, methanyl yellow, chrysophenine yellow, Nippon direct black, Nissen dark blue, Nissen indigo (type), synthetic indigo, Nippon direct blue, Nissen black, methylene blue, methyl violet and rhodamine B. The Nissen colors are originals, developed in their own laboratories, and are especially designed for Far Eastern requirements. The company also refines its own crudes from by-product coke ovens and makes its own sulphuric acid, oleum, hydro-chloric and nitric acids, electrolytic caustic soda and chlorine; and it has a concentrating plant for the recovery of sulphuric acid.

The plant is located at Osaka, on the Ajikawa River, which provides water communication with the Inland Sea and the Pacific Ocean. The crudes are all brought by water transportation. The company employs about 2,000 men. Mr. H. Nakaya is president, the present managing director is Dr. Miyoshi and the general superintendent is Mr. Sakai. Dr. K. Shimomura, the former managing director, resigned on account of ill health, but continues to devote a part of his time to the company in a consulting capacity.

The Mitsui Company confines itself to anthracene products and makes alizarine reds, blues and greens. The native dyestuff industry in Japan is somewhat similar to that in the United States. There is a shortage of cotton vat dyes, they seem to be ahead of us in anthracene products, and the synthetic indigo industry is growing. The prices range comparatively about the same in both countries.

The Sankyo Company makes chiefly pharmaceutical preparations and drugs and it will have a special interest for New York chemists in that Dr. Jokichi Takamine is president. Mr. M. Shiohara is managing director. This plant is located at Shinagawa, and operates the government subsidized pharmaceutical and drug establishment known as Naikoku in connection with its own works. They produce a large number of preparations, including phenol, phenolates and phenol derivatives, aniline, salicylic acid, salicylates (including sodium acetyl salicylate, phenyl salicylate, theobromine sodium salicylate, etc.), acetanilid, phenacetine, cocaine hydrochloride, salvarsan, neosalvarsan, formaldehyde, takadiastase, chloral hydrate, tuberculin and still more, together with ointments, tablets, pills and compounded medicines.

Dr. Hirsch was full of enthusiasm over the National Exposition of Chemical Industries which was held at Uyeno Park, Tokio, from September to November inclusive, 1917. The government gave its official buildings for the purpose, to which a considerable number were added to provide room for the exhibits. Admission was ten sen (five cents) and all school children were taken
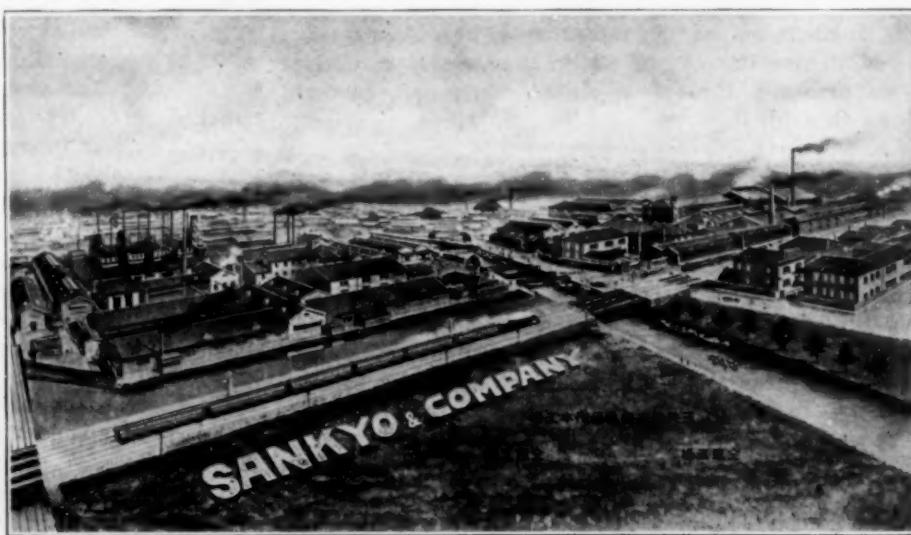
CHEMICAL PLANT OF SANKYO & COMPANY, FHINAGAWA, TOKYO, JAPAN

to see it. A feature that impressed Dr. Hirsch emphatically was the way in which this exhibition brought chemistry home to the people at large. Artistically it was made very attractive and the uses of products were pictorially represented on back drops in booth structures and with wax mannikins. For instance, the Tokio Gaslight Company had a great pile of coal upon which stood a huge, many-armed-god of fire, fully fifteen feet high. Strands of red gauze were blown up from the coal underneath the figure, which gave an impression of flames. In the hand of each of the many

arms was held a pictured plaque, indicating the uses of gas and coal products while ranged in front were many of the products themselves. The use of mannikins in the representations of the many industries gave a human touch to the show that made everyone feel that he understood at least something about it.

It is obvious that the Japanese are resolved to make their chemical industries permanent, and it is doubtful if any method could have been devised to make the people feel it to be a part of themselves more effectively than by their great exposition.

The Design and Operation of a Small Kjellin Furnace*
Manufacture of Electric Steel for Stamp-Mill Shoes and Dies on the Witwatersrand, South Africa
By GEORGE H. STANLEY and W. BUCHANAN

THE design of an induction furnace is very similar to that of a single-phase, core-type, alternating-current transformer, subject to the limitations of non-sandwiched windings and a horizontal position of the secondary. While it is most important with a transformer to generate a minimum of heat and circulate oil or water quickly to carry off the small amount necessarily generated, in a furnace the main object is to convert the maximum of the supplied energy into heat, and prevent its loss by the use of a non-conducting casing.

The action of a current in producing magnetism is of a reciprocal nature. Any change in the number of magnetic lines passing through a closed conducting loop produces an electric current in such circuit, the strength of which is directly proportional to the rate of change of the magnetism, and inversely to the impedance of the circuit. The relation for alternating currents corresponding to Ohm's law for direct currents is

$$E = I\sqrt{R^2 + \omega^2 L^2}$$

where E is the electromotive force,

    I is the current produced in amperes,

    R is the resistance of the circuit in ohms,

    ω is the rate at which the current changes (or angular velocity),

    L is the coefficient of self-induction of the circuit.

The coefficient of self-induction of the circuit may be otherwise thought of as the number of magnetic lines produced through a circuit when unit current flows through it.

CONDUCTIVITY OF SECONDARY

No very precise data appear to be published regarding the electrical resistance of different grades of steel at very high temperatures. It was therefore assumed that the temperature coefficient determined by Fleming and Dewar for pure iron at low temperature would give sufficiently accurate values for molten steel. This coefficient gives the resistance R at any temperature t deg. C., by the relation

$$R = R_0(1 + 0.00625\,t)$$

where R_0 is the resistance at zero Centigrade. The working temperature of the furnace was estimated to be about 1550 deg. C., so the resistance when hot appears to be 10.7 times the value at 0 deg. C.

There is even greater uncertainty regarding the value R_0 for high carbon steel, the resistance of which seems to vary from eight to twelve times that of copper. Ten times the resistance of copper was taken as likely to give an approximate average value, and the specific resistance of the heated metal figured to be $0.64 \times 10.7 \times 10^{-6}$ ohms per cubic inch. The circumference of the channel being 157 inches gives a resistance of 0.0107 ohms per square inch of cross-section. The minimum metal retained in the furnace between heats—900 lbs.—with about 22.5 sq. in. section has a resistance of 0.00048 ohms, while the maximum contents of 2900 lbs. with 72 sq. in. cross-section has a resistance of 0.00015 ohms.

ENERGY REQUIRED

Published data regarding the amount of energy required to melt one ton of steel in the electric furnace show a great deal of variation, depending upon the size and type of furnace. It seems to be the general opinion that the induction type takes rather more power than the corresponding arc furnace, and for the small size considered it appeared as if 900 kw.-hr. would be required per short ton to melt cold steel scrap. As, however, it was intended to pre-heat the scrap in the furnace attached to the mold-drying stove, it was expected that the actual expenditure of electricity per ton of product would be somewhat less than 900 kw.-hr., and the whole plant was designed to be able to give this amount. To supply 900 units every eight hours necessitates an average input of 112.5 kilowatts. Further, since this amount is not possible during the first hour or so when the small quantity of metal in the channel offers a maximum resistance, it becomes necessary to be able to give at least 120 kilowatts continuously with a full furnace. This energy is absorbed with $\sqrt{\dfrac{120,000}{0.00015}}$ or 28,300 amperes, the phase voltage required being

28,300 $\times$ 0.00015 = 4.24 volts. It may be noted that unless the voltage be increased at light load, the energy supplied to the 900 pounds of metal would be 37.5 kilowatts, while it has been found that about 30 kilowatts at full temperature is lost by radiation.

MAGNETIC FIELD

One of the most serious drawbacks to the use of the induction type of furnace is its low power factor (down to 0.25) when used with current of the commonly available frequency of fifty alternations. The reason for this is the excessive amount of magnetic leakage caused by the necessary distance separating the primary from the secondary winding, thus demanding a large component of current at full load which absorbs no power, but simply produces a useless magnetic field.

To calculate the value of this leakage field accurately is practically impossible; but approximations can be made to give results near enough for the fairly close determination of transformer dimensions. The simplest result is obtained by considering the primary coil together with the secondary ring as being removed from the vicinity of the iron core and as equivalent to two parallel and concentric cylinders carrying current flowing in opposite directions; for which case Clerk-Maxwell has mathematically determined the value for the inductance L as

$$L = l\left(4 \ln \frac{d}{a} + 1\right)$$

where L is the inductance of the field,

  l is the length of the cylinder in centimeters,

  d is the distance between the cylinders,

  a is the radius of a circle equivalent to the cross-section of the conductors.

In the case in point, l is the average circumference of primary and secondary, and is therefore $\frac{1}{2}\pi$ (50 + 22) or 112.5 inches, which equals 286 cm.; d is 14 inches and a is assumed to be 4 inches. Therefore

$$L = 286 \left(4 \ln \frac{14}{4} + 1\right) = 1720$$

It will readily be seen, however, that the presence of the laminated core reduces the magnetic resistance of the primary leakage path by about one-third, and thus increasing the above value 10 per cent, giving L as 1892.

The value L was also determined by the more accurate but somewhat laborious method of determining the main leakage paths for both coils, the summation for unit current giving the leakage induction per turn.
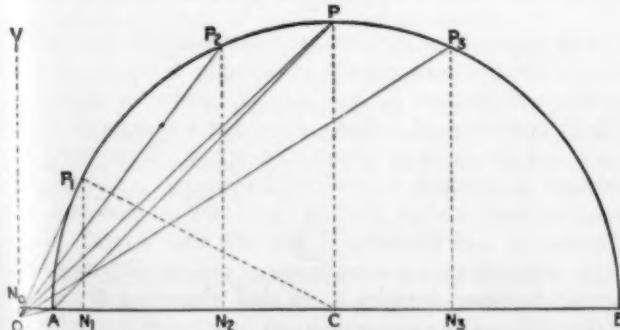
FIG. 1

In this procedure the dividing line of equal magnetic potential for primary and secondary is first calculated; then the mean length of path is determined for a small area, the flux through which can thus be obtained. The same process was repeated for all other sections. The value thus obtained for L was 1870, but since in any such summation the value cannot be too high, certain unobserved paths being left out, L = 1900 is taken as the most likely value. To bring L to henries, or practical units, the result has to be multiplied by 10^{-9}, thus the reactance is $2\pi \times 12.5 \times 1900 \times 10^{-9}$ which equals 0.00015 ohms. (12.5 is the number of cycles in the current to be supplied to the furnace.) This value happens to be exactly the same as the ohmic resistance, so that the tangent of the angle of lag between the resultant current and the applied voltage is unity, the angle is 45 degrees, and the power factor is cosine 45 deg. or 0.707. The magnetizing component of applied voltage with 28,300 amp. as before is 4.24 volts, and the resultant is $4.24\sqrt{2}$, or 6 volts.

In order to obtain the power factor of the primary circuit it is necessary to determine the magnetizing and power component of the open circuit current required by the laminated core. For this purpose a value of 6.3 volts per turn of primary winding is taken—5 per cent increase over the 6 volts computed above being allowed for overcoming the resistance of and forcing the magnetizing current through the primary coil. The magnetic flux passing round the rectangular core, and common to both primary and secondary coils, is given by the relation

$$\varphi = \frac{e \times 10^8}{4.44 \times f}$$

where φ is the magnetic flux,

  e is the volts per turn in the primary winding,

  f is the cycles of the current;

in our case,

$$\varphi = \frac{6.3 \times 10^8}{4.44 \times 12.5} = 11,300,000 \text{ lines}$$

on the usual assumption of a sine-shaped wave.

OPEN CIRCUIT CURRENT

The following tabulation shows the method of arriving at the open circuit current for a magnetic flux of 11,300,000 lines in the core:

Part of Core	Cross-Section, Sq. Cm.	Magnetic Density	Ampere-Turns, per Cm.	Length of Path, Cm.	Ampere-Turns
Limb, inner	950	11,800	6.6	80	528
Limb, outer	950	11,800	6.6	80	528
Yoke, upper	1150	9,800	4.0	135	540
Yoke, lower	920	12,300	8.0	130	1040
Four joints	980	11,500	9200.0	0.1	920
Total					3556

Since the above magnetic density is the peak value, the ampere-turns are also the maximum. Assuming the current to be a sine wave, the peak is $\sqrt{2}$ times the effective value, and the latter is given by dividing 3556 by $\sqrt{2}$. Thus 2500 amp. is the magnetizing current if there were only one turn on the primary coil.

The loss due to hysteresis and eddy currents in the core, assuming the steel to be of good transformer quality, should not exceed 5 kw. at the magnetic density

and frequency stated above. The power component of open circuit current is thus $\dfrac{5000}{6.3}$, or 800 amp., and the total open circuit current is $\sqrt{(2500)^2 + (800)^2}$ which equals 2620 amp.

The current on absolute short circuit with 6.3 applied volts (neglecting primary resistance) is $\dfrac{6.3}{0.00015}$, or 42,000 amp., the power factor being, of course, zero.

Other values for the relation of current to power factor may be obtained by calculation on varying the furnace resistance and assuming the inductance to be a constant. The latter assumption is very nearly true. Thus, when the furnace is one-quarter full of metal, the equivalent radius for the secondary is one-half that originally assumed. The mean value of a for the combination is then $\sqrt{\dfrac{16+4}{2}}$, or 3.16. Using this value in the formula instead of 4 gives $L = 1820$, instead of 1720 for full channel.

Instead of calculating all individual values of the power factor, it is very convenient and sufficiently accurate, with such a very leaky transformer, to use the circle diagram of the equivalent induction motor. This is shown in Fig. 8. In this diagram N_cA is the magnetizing component and N_cO is the power component, drawn to scale and to proper phase; therefore, OA represents the open circuit current to scale. The value of the absolute short circuit current is OB and the semicircle APB on AB gives the locus of the current in value and phase for any chosen voltage. Thus, for a secondary current represented by AP_2 the primary current is $\dfrac{OP_2}{n}$ (where n is the number of turns in the primary winding); further, P_2N_2 represents the power component of the furnace current, and $P_2N_2 + N_cO$ divided by the length OP_2 gives the value of the primary power factor; that is, the power factor equals the cosine of the angle OP_2N_2 or the equal angle P_2OV. The highest power factor is at the point where this angle is a minimum: obviously given at point P_1 where OP_1 is a tangent to the circle. In our particular case, OP_1 is almost exactly 10,000 amp., and the power factor reaches 0.91.

POWER FACTOR

The maximum true power consumed in the secondary is given at point P vertically above the center of the circle. This being equal to the radius, its value is ½ (42,000 — 2,500), or 19,750 amp. This value when multiplied by the applied voltage 6.3 gives 124 kw. The furnace current represented by AP is then $19,750 \times \sqrt{2}$, or practically 28,000 amp.; the corresponding primary current OP is 30,300 amp., and the primary power factor is $\dfrac{19,750 + 800}{30,300}$, or 0.675.

It will be clear from the diagram that any attempt to overload the furnace by adding metal, thus reducing the resistance of the secondary and increasing the primary current beyond about 30,000 amp. would result in less heat being obtained, although the generating plant would get hotter, owing to its giving a higher volt-ampere output. The two points P_2 and P_3 are chosen to illustrate this important feature. In both positions, the true power absorbed by the furnace is 113 kw., but, while this is obtained at P_2 with 23,500 amp. at 0.8 power factor, the same absorption at P_3 requires 35,500 amp. at only 0.53 power factor.

There can never be any advantage in working the furnace outside the limits defined by the first quadrant; in fact, it can seldom be economical to push the current even to within 10 per cent of the maximum power value when the loss and the heating of the generators are considered. When the input current is but 27,000 amp., the power available for heating is still 121 kw., or only 2.5 per cent from the maximum, but the power factor reaches 0.74. The exciting current required by the generators in this case would be considerably less than when giving 30,000 amp. at 0.68 power factor.

PINCH EFFECT

One consideration which forms a limit to the minimum amount of metal left after each cast is the pinch effect, which is due to the attractive force existing between parallel conductors carrying like currents. The secondary conductor, being fluid, is liable to be broken by such pressure. In the event of the cross-section not being absolutely uniform all around, the break occurs at the place of least cross-section, where the current density is greatest. This phenomenon has been investigated by Dr. Hering, who gives for an open rectangular channel, whose depth is twice its width, the critical current density as $895 \sqrt{\dfrac{G}{H}}$ in amperes per square inch, G being the specific gravity of the molten metal, and H the depth of channel in inches. For example, in a channel 8 in. by 4 in. and $G = 7$, the critical current density is 835 amp. per sq. in. of original section, or a total of 26,800 amp.

Besides this internal stress there is a bodily force acting on the molten conductor, due to the repulsive effect from the unlike current of the primary. The magnitude of this force, with 30,000 amp. in conductors 14 in. apart, is 2.83 lb. per in. of circumference. With a full channel of 72-sq.-in. section, the same pressure would be produced if the molten metal revolved at a speed of about 14 revolutions per minute. The elevation of the outer edge when the metal is very fluid has no doubt given rise to the mistaken idea that the metal revolves bodily.

PRIMARY COIL

The choice of a suitable primary winding was determined by the best output obtainable from the generators, and limited by the size of conductor available, which consisted of a finely stranded rectangular strip, having a net area of about 0.24 sq. in. With two conductors in parallel, a current of 600 amp. could be carried without undue heating, provided a moderate air circulation was available. The coil was wound, therefore, with 56 turns, a tap coming out at 45 turns connected to three terminals, so that changing from full coil to tap, or the reverse, could be carried out without loss of time. When working on full coil and a furnace

current of 28,000 amp., which corresponds to 30,300 amp. through a single-turn primary, the primary winding requires $\dfrac{30,300}{56}$ or 540 amp. at $6.3 \times 56 = 353$ volts. If working on the tap, 670 amp. at 284 volts are necessary; some scope is thus provided for working the generators to the best advantage. The resistance of the coil at 200 deg. C. is 0.006 ohms; the loss at 540-amp. input is thus 1750 watts. The electrical efficiency, including 5000 watts core loss, is equal to the true power consumption in the secondary divided by the same figure increased by the core and ohmic losses in the primary. This amounts to $\dfrac{124}{124 + 1.75 + 5.0} = 95\%$ at maximum power. This is much higher than would be obtained with an induction motor for a similar output.

PRE-HEATING OF SCRAP

It has already been mentioned that normally the scrap steel is raised to a red heat in a coal-fired furnace before being fed into the electric furnace, and it will be obvious that where coal is reasonably cheap it must pay to pre-heat as much as possible and thus increase the output for a given supply of electricity. The limit to such pre-heating is fixed by the excessive oxidation of the steel at high temperature when exposed to direct action of the heated gases in the reverberatory furnace, although this may be prevented to a great extent by keeping a smoky or reducing flame over the metal.

It is given in textbooks that about 360 kw. hours of energy can heat and melt one ton (2000 lb.) of steel at about 1450 deg. C. if it could be applied without loss. The specific heat of cold steel is about 0.115, and it is usually assumed that it increases 1 per cent per 10 deg. C. at 1600 deg. C. it would, therefore, be about 0.3, so if the metal is heated, say, 200 deg. above its melting point, the added energy is 64 kw. hours per ton. If the metal is put into the furnace at, say, 480 deg. C. instead of at 30 deg., the average specific heat being 0.115×1.24 or 0.14, the energy saved is 65 kw. hours per ton, amounting to fully 15 per cent of the above 424 units.

It has been found in operation that a supply of 25 kw. to the furnace, in addition to the 5 kw. taken by the transformer, is sufficient to provide all loss by radiation and conduction with a furnace temperature of about 1600 deg. C.; but in actual working, owing to charging and testing, the energy required amounts to about 670 units per ton when casting about 2200 lb. every eight hours; being reduced to about 600 units when casting the same quantity of metal every six hours.

During August the energy supplied to the furnace was 58,656 kw. hours; there was produced 68.6 tons of net castings, the estimated metal melted being 76.3 tons, showing 770 units per ton melted. This energy included the amount required to dry and prepare three new furnace linings.

FREQUENCY CONVERTER

The current conversion is effected by a motor with a generator on each side directly coupled to give the required single-phase current, the armatures being connected in series. The only available generators were "inductor" alternators of a rather out-of-date type, and were converted from 25-cycle into 12.5-cycle machines by altering from six to three poles per side. When giving an output of 600 amp. at 320 volts, with a power factor of 0.68, the true power is 130 kw., the armature drop 14 volts, and the exciting energy for both generators 60 amp. at 75 volts. The output desired from the motor was 220 b.hp., this being required when the generators are giving 130 kw. with an estimated efficiency of 80 per cent; unfortunately, the only motor that could be obtained was one that had originally been built to give 820 b.hp., so that if used as it stood the efficiency would be poor and the power factor very low when working at about 220 hp. Fortunately, it was not very difficult to alter the stator winding from a rather inefficient parallel winding to one in which these windings were connected in two series. Although the motor must work with little rise in temperature, its efficiency is now probably 4 per cent lower than would be obtained with a motor designed to give, say, 250 hp.

OPERATING TESTS

The following readings are taken from the running log. The actual value of the power factor at any particular load could only be obtained by using a power factor meter; but, instead, the volts, amperes and wattmeters are ready every half hour, which gives in practice sufficiently accurate results:

FULL PRIMARY WINDING (56 Turns)			PRIMARY ON TAP, (45 Turns)		
Voltmeter	Ammeter	Wattmeter	Voltmeter	Ammeter	Wattmeter
296	300	240	310	402	18
316	312	282	300	392	66
316	320	318	296	418	120
312	322	360	290	438	168
306	318	408	275	470	222
310	319	450	275	480	276
			265	498	330
Av. 310	315	......	258	516	378
Kva., 97.65			250	540	432
Kw., 84			253	555	480
Power factor, 86%					

In the second case, the watt reading shows a nearly constant difference, so the average kw. is 103. Considering this to be constant, which it appears very nearly to have been, the average kv.-a. over each hour is 120 at 400 amp., 124 at 438 amp., 131 at 483 amp., 134 at 516 amp., and for the last half-hour 138 at 549 amp., the corresponding values of the power factor are 0.86, 0.83, 0.79, 0.77, 0.75; the latter is the value for the equivalent of $549 \times 45 = 24,700$ amp. in primary for a single turn winding.

During the month of January, 1917, the furnace meter registered 44,940 electrical units, while the meter at the transformer substation showed 71,800, giving an overall efficiency of 62.6 per cent. For August, the furnace received 58,656 units, and the substation meter registered 89,700, giving on the greater average output an efficiency of 65.5 per cent.

OPERATING COSTS

Working costs are somewhat high on account of the small scale of the operations, labor in particular being a very big item. In fact, the same number of hands could probably turn out two or three times the present output with a larger furnace. Three eight-hour shifts are worked, and each of these requires an electrician in charge of the electrical plant and a furnaceman or molder in charge of the furnace. For this latter it has

been difficult to secure suitable white workmen, and colored labor is employed, therefore, on some shifts under supervision of the electrician. Consequently, the number of white furnacemen on the pay roll varies between one and three. The actual furnace charging is done by "Cape boys," of whom five or six are employed in all, and about fifteen natives are used in breaking up scrap and miscellaneous labor. All are under the charge of a works manager, so that the wages bill and supervision fees amount to about £400 ($1940) per month. Electric power is the next big item, and amounts to close on £200 ($970) per month, and the cost of scrap at £1 ($4.85) per ton is third in order of magnitude.

The largest output so far was obtained in July, 1917, when 73 tons of castings were produced at a works cost of less than £14 ($67.90) per ton. In August nearly 69 tons were made, so it is quite safe to assume an average output of 60 tons per month. For this the costs would be approximately as follows:

	£	$
Scrap, 70 tons, @ £1	70	339.50
Pig iron, 1½ tons, @ £20	30	145.50
Aluminum, 30 lb., @ 2/-	3	14.55
Magnesite (calcined), 2 tons, @ £18	36	174.60
Miscellaneous stores	15	72.75
Repairs and renewals	15	72.75
Tools, etc.	5	24.25
Electric power	200	970.00
Cartage	30	145.50
Miscellaneous sundries	20	97.00
Salaries, wages, and supervision fees	400	1940.00
	£824	$3996.40
Per ton nearly	14	66.59

ECONOMIC CONSIDERATIONS

In concluding this account it may not be out of place to call attention to the exceptional opportunity offered by present conditions and prices to make a serious commencement with the iron and steel industry.

Apart from the plant described, small as it is, there are only two other concerns turning out such steel in any quantity. Both work only on scrap, and only one of these has melting furnaces, the other merely reheating and rolling. Both together are quite inadequate to supply the local demand if importation from oversea became impossible. Further, the supply of suitable scrap though large is not unlimited, and in some directions there is an actual shortage of raw material already. So in this direction also the country is likely to be thrown on its own resources before long.

From the point of view of the various iron foundries also, the position is much more serious and must give rise to careful consideration of the possibility of local production. Pig iron of first quality at present approximates in price to £25 ($121.25) per ton, while the prewar price was about £9 ($43.65). At first sight even the latter figure seems attractive enough to encourage local production, but it must be remembered that the whole South African consumption—as pig—is comparatively small and a large output would only be disposable in the form of steel. Even as cast iron, however, the present requirement is enormously greater than before the war; much casting work is being done for the mines and other consumers which formerly was imported, and if only the iron were available at reasonable price, a large industry could be created in the manufacture of pipes and other agricultural machinery. But a very much greater tonnage could be absorbed in the form of steel, and without attempting to cater to all the large and varied requirements now imported, comparatively simple products could be made.

Synopsis of Recent Metallurgical and Chemical Literature

Potash from Blast Furnace Gas.—Two papers read before the Cleveland Institution of Engineers (England) and published in *The Iron and Coal Trades Review*, Jan. 18, 1918, deal especially with cleaning blast furnace gas and the recovery of potash. The first paper, by A. LENNOX LEIGH, described an installation of a gas-cleaning plant at the North Lincolnshire Iron Company's works. Savings were effected on boilers and stoves by the use of cleaned gas. The author states that so far as a general statement for all furnace plants can be made of the consumption of gas under different conditions, the cleaning of all the gas and its use for boilers and stoves shows a better result than cleaning a portion and using this in the blowing and power gas engines required for the furnace, when taking into account the other economies, the increased value of the cleaned gas and the extra capital outlay for a gas-engine installation. To indicate this the following approximate gas distribution can be compared; it will be noted in the figures given, the reduction of the amount of cleaned gas used for boilers is taken as 25 per cent, not 50 per cent; the reason for this is because the evaporation with uncleaned gas in the plant mentioned is probably lower than in most districts, and an attempt is made to give as general a comparison as possible; any of the figures may have to be decreased or increased for particular circumstances, but to make the comparison of more value it ought to be as near as is possible with average conditions:—(1) Uncleaned gas with boilers and steam engines; (2) cleaned gas with boilers and steam engines; (3) part of gas cleaned for the blowing and power gas engines required for the furnace; (4) cleaned gas with blowing and power gas engines.

	1 Per Cent	2 Per Cent	3 Per Cent	4 Per Cent
Stoves	40	30	40	30
Blowing and power	40	30	15	15
Loss	10	10	10	10
Total required	90	70	65	55
Uncleaned spare gas	10	..	35	..
Cleaned spare gas	..	30	..	45
	100	100	100	100

The author's summary of advantages is as follows:

(1) Economy in gas for boilers.

(2) Economy in gas for stoves.

(3) Fewer stoves required and probably fewer boilers.

(4) Better control of furnace operations and saving in cleaning stoves, boiler flues, etc.

(5) Additional source of income from the larger volume of spare gas of an increased value for the production of cheap power and coal economy.

(6) Recovery of potash as a by-product.

The second paper, by KENNETH M. CHANCE, dealt with the commercial aspects of the situation. He said with the present rate of pig iron production in England it may be safely estimated that not less than 200,000 tons of potash are being fed into the blast furnaces each year. Of this, in round figures, three-quarters (or 150,000 tons) passes through the furnaces and away in the slags in insoluble form, and one-quarter

(or 50,000 tons) is volatilized and carried from the furnaces in the gas in the form of carbonate, chloride or cyanide, usually a mixture of all three. Of this 50,000 tons, a small proportion is carried down into the dust catchers and down-comers with the heavy dust, and another small proportion is recovered from the stoves and boiler flues, after the combustion of the gas, in the form of sulphate of potash, into which it has been converted during the process of combustion. The remainder, which may be estimated as being in the neighborhood of four-fifths of this 50,000 tons, escapes with the gas up the chimneys and is liberated into the atmosphere. Of all the potash charged into the furnaces, therefore, at the present time, not more than 5 per cent is recovered, and of that 5 per cent quite a considerable proportion is thrown away with the heavy dust as having no value. The British Cyanides Company, Ltd., and the North Lincolnshire Iron Company have carried out a long series of experiments on a practical scale and have devised two methods of recovery. One process aimed to volatize the potash from the furnace, as carbonate is not recommended as a commercial method. A simpler and more economical method of recovering the potash charged into a furnace manufacturing ordinary pig-iron is by adding to the charge an alkaline chloride, of which common salt is the one most readily available. This has the effect of converting the silicates of potash into chlorides, which are volatilized at ordinary working temperatures into the gas in that form, substituting soda for potash in the slags, and there is ample evidence to show that, generally speaking, this method can be relied upon to render available for recovery from 70 per cent to 80 per cent of the potash charged into the furnace in contrast to the bare 5 per cent now recovered.

The author stated that a company has been formed entitled the British Potash Company, Ltd., the shareholders in which are the two firms mentioned, John Lysacht, Ltd., and the government. In the constitution of this company particular attention has been paid to the importance of insuring that its financial strength shall be sufficient to establish a national potash industry capable of holding its own against external competition, and, until this has been secured, dividends upon the share capital are limited to 6 per cent per annum. The whole of the knowledge and experience gained by these firms, together with their inventions relating to the recovery of potash, have been placed at the disposal of the potash company in consideration of the right to subscribe at par for half the shares in that company, and no firm or individual has either asked or received any other consideration of any sort or kind whatever for money expended or services rendered up to the formation of this company. The remaining half of the shares have been taken at par by the government. The shares owned by the private interests, after provision has been made for ample reserves, are to receive by way of dividend out of profits a certain fixed sum per ton of potash produced each year, and the balance of the profits made by the company will be distributed as dividend on the government shares. The proposition which the company lays before the potential suppliers of raw material is that, subject to such arrangements as to detail as will insure the raw material being supplied in such a form that the potash

can be economically recovered from it, their raw material shall be purchased by the potash company at a price which will insure them an immediate profit per ton of potash contained in it which is identical to the profit per ton payable by way of dividend on the shares in the potash company subscribed by the private interests. These dividends on the privately owned shares can only be paid out of profits earned subsequent to the establishment of these large reserves, whereas the profit to the suppliers of the raw material is part of the purchase price of that material. That sum in the case of chloride of potash is 25s. per ton, and is equivalent to a potential profit of from $4\frac{1}{2}$d. to 9d. per ton of pig iron.

This is a figure of profit on a by-product of the manufacture of pig-iron and not the purchase price of that by-product, but it is obvious that no company can guarantee a profit on the raw material which it purchases unless it can make a profit on the finished commodity that it has to sell, and therefore, just as in the case of the potash company, this profit of 25s. per ton to the privately owned shares varies upwards and downwards to a certain extent as the cost of production decreases and increases, so arrangements will have to be made with those who supply the raw material that there shall be variation upwards and downwards of this figure of 25s. per ton according to the effect which the form in which this raw material is produced has upon the cost of manufacture of the finished product. Under this arrangement, the state is in a position to insure that the most rigid economy in manufacturing is inforced, and, as their success will depend entirely upon their obtaining ample supplies of suitable raw material at low prices, the potash company will be bound to train and maintain a staff of skilled engineers and research chemists whose duty it will be to assist the suppliers of the raw material to produce the maximum quantity at the minimum cost and to keep their plants running at the greatest possible efficiency. As also the cost of transit from the source of supply to the central factories will be a large item in the cost of manufacture, the potash company will erect a central factory in each district which will undertake to supply sufficient raw material to keep that factory in full operation. After careful consideration it has been determined that the smallest unit consistent with economy is a factory whose output will be not less than 25,000 tons of chloride of potash per annum. The first of these factories has been erected at Oldbury, and is in a position to commence manufacturing operations, and it is the hope and belief of those whom, as managing director of the potash company the author represents, that the company shall be compelled to erect three or four similar factories in other districts, the most important of which is obviously Cleveland. The development of this industry will be watched with interest

Pyrometry

Calibration of Optical Pyrometers.—Wien's distribution law has been universally used in the interpretation and extrapolation of experimental results in the calibration of optical pyrometers such as the Le Chatelier, Wanner, Morse, Holborn and Kurlbaum pyrometers, or the Shore pyroscope which measure temperature by measuring the intensity of radiation of a definite wave

length emitted from a theoretical black body. This law is stated as follows:

$$\phi(\lambda, \theta) = \frac{Ce^{\frac{c}{\lambda\theta}}}{\theta^5}$$

where $\phi(\lambda, \theta)$ $d\lambda$ is the intensity of radiation of a black body at absolute temperature θ produced by waves of length between λ and $\lambda + \delta\lambda$ and C and c are constants. F. E. Wood criticizes this formulation in the *Philosophical Magazine*, Vol. 35, page 190 (Feb. 1918, from a mathematical point of view, and shows it to be inconsistent with other results following from Wien's assumptions. He derives a new law, which is shown to be consistent with correlated formulae as follows (notation as before):

$$\phi(\lambda, \theta) = \frac{Ce^{-\frac{c}{\lambda\theta}}}{\lambda^5}$$

Iron and Steel

Metallurgical Treatment of High Speed Steel—J. L. Thorne recently presented a paper before the Steel Treating Research Society in Detroit, giving considerable information on this subject. He warns the purchaser from buying steels by trade name only, since there have been instances where the composition has been materially changed without notice to the user. The high speed steels on the market now are comprised within the following limits, a third column giving a good chemical specification.

	Range	Proposed
Carbon	0.47 to 0.91%	0.65%
Silicon	0.12 to 5.00	0.12
Manganese	0.12 to 0.67	0.25
Sulphur	0.008 to 0.057	0.02
Phosphorus	0.006 to 0.051	0.02
Chromium	1.50 to 5.52	3.5
Vanadium	0.13 to 2.5	1.0
Tungsten	11.74 to 22.27	18.0

As the steel is purchased it is sampled and analysed. Close adherence to chemical specification is impossible and undesirable. Sulphur and phosphorus should be kept low; manganese as low as necessary to inspire against harmful sulphur effects, and silicon low to prevent brittle silicide segregations. The tungsten-chromium-carbon combination is of course responsible for the "red-hardness"; while vanadium, originally added merely as a scavenger, increases the elastic limit and the resistance to wear and shock. New high-speed stock should have a hardness slightly under Brinell 250 or scleroscope 35 in order that it may be machined readily. Microscopic examination is also undertaken before the material is accepted, looking particularly for forging cracks, surface decarbonization, uniform structure, segregation and ingotism.

After the tool has been formed and sent to the hardening room, it should first be given a "soaking" heat at from 1500 to 1800 deg. F. to avoid expansion strains and cracks if suddenly put into the high hardening heat. When uniformly heated, it is transferred to a high-temperature furnace, whose heat is as uniform as possible, controlled with standardized pyrometers, and allowed to remain there a certain specified time. This time is automatically registered by colored lights and warning buzzers, so that at the proper instant the tool can be removed and quenched—preferably in oil, circulated over cooling coils to maintain a uniformly low temperature. Taylor discovered that to get the maximum red-hardness

this quenching temperature must be far above the critical temperature—approaching that where the tool actually softens. This hardened tool is then "drawn" in a low temperature furnace—bearing in mind that the metal progressively softens up to a point lying between 700 and 800 deg. Fahr., from which to about 1100 deg. it increases in hardness with the temperature.

In a very extensive test of nearly a thousand drills made of all available domestic and foreign high-speed steels, it was discovered that the most efficient tools exhibited a great resemblance in microscopic structure, regardless of their manufacture or heat treatment. This has led to the adoption of the so-called "standard structure" to be looked for in experimenting to discover the proper heat treatment to give a new lot of metal. Start with several samples and subject them to various temperatures for various times approximating the expected conditions; a microscopic examination will then show that one which nearest approached the standard structure. As the temperature and time of this piece is known, proceed to another set treated at temperatures and times slightly above and below the first approximation. In this way, the third series will give the exact heat treatment which will produce the desired structure. Finished tools are then run on an experimental drill press, and their work compared to that done by one of a set of control tools, and reported as so much plus or minus standard.

Malleable Cast Iron.—In a discussion of the necessary characteristics of successful production of "whiteheart" castings, Mr. E. Adamson, in a paper read before the Staffordshire Iron and Steel Institute, Jan. 12, 1918, presented an interesting tabulation of the role played by the chemical composition, reproduced below:

	Si	S	Mn	Total Carbon
Separation of graphite or free carbon is *induced* at a temperature which is lower	the higher the Si	the lower the S	the lower the Mn	the higher the total carbon
The rate of separation of graphitic carbon is less the lower the temperature and	the lower the Si	the higher the S	the higher the Mn	the lower the total carbon
Combined carbon corresponding to equilibrium at a given temperature dimishes with	increasing Si	lower S	lower Mn	higher total carbon

The author remarks that it is important to note that the separation of graphitic carbon once induced will continue at lower temperatures and that graphitic carbon begins to form in the molten iron. Hot metal, for a white iron casting, must therefore be retained in the ladle a minimum time, and annealed carefully to prevent rapid precipitation of free carbon.

The facts noted in the column headed silicon were published in 1902 by Charpy and Grenet, and are understood well enough to require no further comment. The total carbon rarely amounts to less than 3 per cent; 2.75 per cent is hard to anneal, but will be harder and stronger after a longer annealing at higher temperature. While it is possible to get good "white-heart" castings with sulphur as high as 0.25 per cent, the margin of safety in annealing is much greater if sulphur is much lower, say, 0.05 per cent. A high sulphur, under-annealed casting is brittle, over annealed it will exfoliate. Manganese is not capable of masking the ill effects of sulphur, oft-repeated statements to the contrary. Phosphorus is quite safe up to 0.25 per cent.

Recent Metallurgical and Chemical Patents

Production of Metallic Nitrogen Compounds. — MATHIAS SEM, of Christiania, Norway, proposes to produce cyanamids by introducing a carbide in the form of dust, together with nitrogen into a reaction chamber. The nitrogen as well as the carbide should be preheated to about 700-800 deg. C., and before the process is started the brickwork of the furnace is also heated up. The exothermic character of the process is utilized to maintain the necessary temperature in the furnace and partly to bring about a very rapid nitrification. (1,256,-935, Feb. 19, 1918).

Cyanides and Ammonia.—PAUL A. STARKE of Berkeley, Cal., patents the production of cyanides from natural gas and ammonia in the presence of a catalyzer of sodium carbonate, magnesium oxide and iron. The gases are passed through the reactive substance in a retort heated to 1,000 deg. C. The cyanides formed are recovered by lixiviation and crystalization. (1,256,272, Feb. 12. 1918). In another patent the same process is used to produce ammonia from natural gas and air. In this case a high pressure is used and a temperature of from 400 to 800 deg. C. The ammonia is absorbed as sulphate or liquefied. (1,256,273, Feb. 12, 1918).

Miscellaneous Chemical Process and Products

Sulphuric Acid and Salt Cake from Niter Cake.— A method of decomposing niter cake incidental to sulphuric acid manufacture is patented by LAURENCE T. SHERWOOD, of Connellsville, Pa. By this process the heat of combustion of the sulphur or pyrites is utilized by a simple apparatus for the decomposition of the niter cake and the decomposition of the niter cake furnishes sulphur-oxides which are used along with the sulphur-oxides of combustion in the manufacture of sulphuric acid; thus an economy of fuel is affected. (1,255,474, Feb. 5, 1918).

Electrical Insulating Compound.—WILLIAM T. CUSHING of Milwaukee, Wis., patents an electrical insulating compound, the patent being assigned to the Cutler-Hammer Mfg. Co., of Milwaukee. The composition comprises asbestos and a binder including a varnish of East India gum, China wood oil and rosin and an oxidation retarder of stearin pitch and coal tar pitch in the proportion of approximately two parts of the former to one part of the latter. (1,255,139, Feb. 5, 1918).

Purifying Barium Sulphide.—W. E. PRISK and H. R. HARRISON of Halifax, Nova Scotia, patent a method of purifying barium sulphide by arranging the apparatus so that the solution is passed alternately through a plurality of filters, containing manganese dioxide and calcium carbonate, alternately, the solution being subject to the action first of one of these materials, and then of the other, and the process being continued until all of the impurities are removed. After the solution is thus purified, it may be used for the preparation of insoluble salts of barium, such as barium sulphate, and these salts may be used commercially as desired. (1,256,593, Feb. 19, 1918).

Manufacture of Ammonium Nitrate.—REIDAR BLOM, of Rjukan, Norway, describes a process of making highly concentrated solution of ammonium nitrate or even this salt in the solid state directly by means of the dilute acid. The process is based upon the observation that solutions of ammonium nitrate are excellent absorbents for ammonia gas. Therefore the dilute solutions of ammonium nitrate obtained by neutralizing ammonia water with dilute nitric acid or in any other way may be used for absorption of ammonia gas, and the ammoniacal solution so obtained is neutralized with dilute nitric acid. By repeating at will these operations of absorption and neutralization it is possible to obtain saturated solutions of ammonium nitrate or a precipitation of the solid salt respectively the cost of evaporation thus being reduced to quite a minimum or even totally eliminated. (1,256,513, Feb. 19, 1918).

Refractory Material.—HANS M. OLSON, of Lompoc, California, patents a heat-insulating composition consisting of infusorial earth in a finely divided state, and a binder of sodium sulphate, aluminum sulphate and lime, the infusorial earth being from 75 per cent to 95 per cent of the entire mass, and the binder from 5 per cent to 25 per cent. (1,257,922, Feb. 26, 1918).

Hydrocarbon Coke. — R. P. PERRY, of Montclair, N. J., patents a process of coking coal-tar pitch and similar liquid materials by heating the material in liquid form in comparatively thin films on a moving surface. The patent is assigned to the Barrett Co. of New York City. The process is equally applicable to the residue from petroleum refining which is usually coked by continued high heating in the stills, thereby greatly shortening their lasting qualities. The apparatus patented is similar to a film dryer and delivers coke continuously by a hot cylinder rotating in a liquid bath, catching up some of this liquid, coking same and delivering it to a bin during the rotation. (1,257,959, Feb. 26, 1918).

Electrolytic Processes

Electrolysis of Foul Copper Sulphate.—F. L. ANTISELL of Perth Amboy, N. J., utilizes the following equipment for the electrolysis of copper sulphate solutions containing large amounts of such impurities as iron salts: A rectangular tank with cathodes suspended near either side, the tank itself having filling and drain pipes. Supported within the tank and between the cathodes is a smaller rectangular container containing granular gas-house carbon, and provided with independent filling and drain pipes. The sides of the container may be of rotary cut wood veneer, in case the container is to act as a diaphragm; otherwise it may be latticed or consist of wire netting. The granular carbon acts as the anode, being energized by carbon rods immersed in the container.

Using the wood diaphragm, a good deposition of copper may be had from solutions containing as low as $\frac{1}{2}$ per cent copper, and at the same time increase the acid content of the solution by the use of H_2SO_4 as a depolarizer and circulating same through the anode. The cathalyte is also circulated. The voltage is reduced for several reasons. One is that the numerous points of the crushed carbon present areas of low-surface tension as well as a greatly increased surface of collection where the oxygen is easily liberated, thus reducing the

resistance between terminals. The veneer separates the anolyte from the catholyte sufficiently so that any ferrous iron in the solution will act as a depolarizer, and ferric iron cannot migrate to the cathode with correspondent reduction of current efficiency.

In case a perforated container is used, the solution to be electrolyzed is entered through the crushed carbon and drained from the outer tank. This permits a very high anodic efficiency, which is often as low as 5 or 6 per cent when depolarizing with SO_2 gas, but which attains 80 per cent in this method, with consequent decrease in voltage. The voltage of a tank using an insoluble lead anode after being in service a short time is about 1.20 volts at the anode. In addition to this is an ohmic resistance of about $\frac{1}{2}$ volt (when operating at a current density of 16 amp. per sq. ft.), due to the lead oxide which rapidly forms on the anode. The counter electromotive force of the carbon anode is about 0.35 volt, at which plating begins. At 10 amp. per sq. ft. the voltage increases to 1.30, and the ampere efficiency is maintained at nearly 100 per cent. The power input is, therefore, materially lowered.

In electrolzing leach solutions containing copper and iron, it is usual to continue the electrolysis only as far as the time where the ampere efficiency drops below 80 per cent, when the balance of the copper is precipitated upon iron, at the expense of the iron, sulphuric acid, and large labor cost. With the present cell, it is claimed that solutions containing as high as 50 grams of iron per liter have been successfully electrolized. (1,239,443, Sept. 11, 1917.)

Aurocyanide Electrolysis.—U. C. TAINTON of Johannesburg, Transvaal, proposes to recover gold and silver from cyanide solutions with high base metal or low free cyanide content by the aid of an electrolytic cell illustrated in Fig. 1, having as rotating cathodes 13 a disk of wire mesh, or a thin sheet with serrated arms cut in it designed to pick up and hold metallic threads which may be introduced with the solution. The anodes 19 are of lead, encased in a non-conducting rim and porous diaphragm 22, to prevent the anode products from mixing with the catholyte and causing resolution of the precipitated metal. The anode compartments may also be partly filled with alkaline sulphate solution to prevent disintegration of the metal, and are provided with vent pipes 20 for the escape of gases generated. The rich solution enters the casing through pipe 32, and part of the metal is precipitated in the meshes of the first rotating anode as it passes through. High current density and rapid rotation will cause the
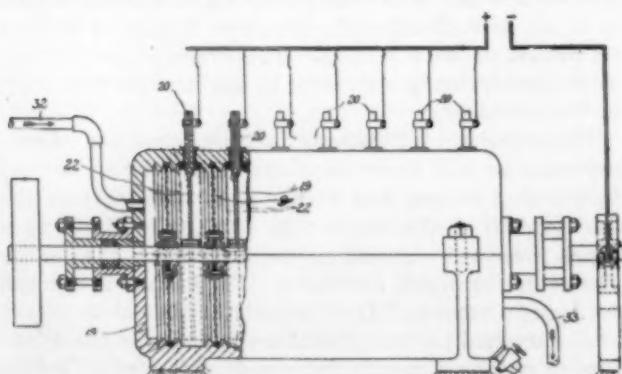
incoherent deposit to become detached and carried along with the electrolyte through successive openings in the anode compartments and whirling cathodes until the solution carrying substantially all the values as finely divided metallics is drawn off through pipe 33 and settled or filtered as desired. (1,251,302, Dec. 25, 1917.)

Nickel-Copper Separation. — GEORGE A. GUESS of Oakville, Ontario, patents a process of separating nickel from copper by the electrolysis of nickel-copper anodes in an electrolyte of nickel sulphate containing an insoluble reagent, such as alkaline earth carbonate of hydrates, preferably limestone. The reagent is kept out of contact with the cathode by means of a porous diaphragm. As the nickel and copper sulphates form at the anode, the copper sulphate is precipitated on the limestone, forming insoluble copper carbonate and calcium sulphate, while the nickel migrates to the cathode and is plated out of solution. (1,251,511, Jan. 1, 1918.)

Filter-Press Electrolyzer.—H. T. SHRIVER of West Orange, N. J., has patented improvements to the leaves of the ordinary filter-press type electrolyzer, Fig. 2, commonly used in the production of oxygen and hydrogen from water. He casts gas chambers above each plate, into which the liberated gas enters through ports 22, and from which they escape over the top of the partition 21 into continuous ducts 13 or 14, and thence to separate tanks for their reception. In this manner the electrolyte is entirely absent from the gas ducts, preventing the customary short circuiting and loss of effi-
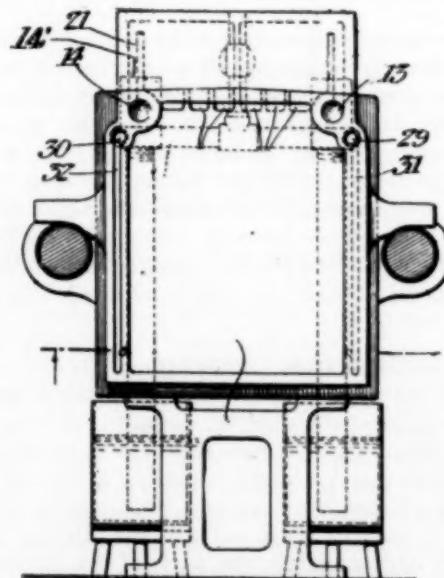
FIG. 2. OXYGEN AND HYDROGEN GENERATOR

ciency due to this cause, since the pressure on the electrolyte is such as to keep its level continuously below the tops of the partitions 21. The supply of pure water necessary to replace that electrolyzed is introduced through the continuous ducts 29 and 30, from which it enters each section as needed through grooves 31 and 32 cast in the side of the leaves. The water enters the bottom of the section, and diffuses upward through the denser electrolyte, each section being automatically kept at the proper density and elevation by maintaining a proper pressure on the fresh water supply. (1,239,-530, Sept. 11, 1917.)

FIG. 1. ELECTROLYTIC CELL FOR CYANIDE SOLUTIONS

A New Experimental Retort for Dry Distillation

By F. E. COOMBS

DURING the course of a long series of dry distillations it became desirable to control the temperature in varying limits, and to have means for easily and quickly opening, cleaning and closing the retort, while still hot. Nothing of this nature being available in stock apparatus the form described in this article was devised and used successfully.

The accompanying illustration shows clearly the construction of the retort and vessel for holding a bath of suitable fused heating means. The original apparatus was put together from ordinary iron pipe and fittings and worked satisfactorily. It is, of course, a better plan to make this outfit from pattern as a casting, for which either iron, brass, aluminium or any other preferred material may be used, according to circumstances.

The drawing shows, 1, an iron vessel to hold melted lead, sulphur or caustic soda, according to the temperature range required. This vessel is conveniently supported and heated and a thermometer dipped into the bath for control of heating.
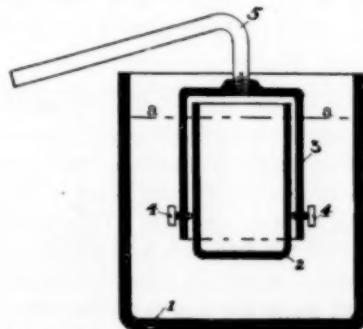
CROSS SECTION OF RETORT FOR
DRY DISTILLATION

A container, 2, with a very loosely fitting cover, 3, is filled with the assay and immersed to a point where the level of the fused bath (a) will be safely below the top of the container; the cover is firmly fixed to the container by means of three screws, 4, so that there is an approximately even space of about ¼ inch between cover and container, serving as a seal-channel, which may be made as deep as the conditions of the work demand. That is to say, if a distillation only is required and the internal pressure is not to be much above the atmosphere, both container and cover may be fairly shallow; but if gases are to be collected, or the vapors forced against material resistance in the way of absorbers, etc., then proportionate depth of seal must be provided in designing the container and cover.

A gooseneck, 5, is screwed into the top of the cover, and in the case of small apparatus this will be used as a handle and is held in the usual ringstand clamp when in use in the bath.

A section of 4-in. pipe 7 in. long will hold about 20 lb. of melted lead and can be brought to and kept in fusion with a large Bunsen burner. A bath of this size will permit a container about 3 in. by 2½ in. to be immersed, cold, without "freezing" the lead if brought well above the melting point.

In tests with substances whose heat-reactions are not definitely known, this form of retort saves breakages of condensers and tubing, for swelling of the assay and stoppage of the gooseneck simply forces exit through the seal. It goes without saying that the retort and all of its parts must be dry when placed in the hot bath, or there will be steam explosion and scattering of lead or hot material. Further, in bringing a solidly filled bath of lead to fusion, melt from the top, to avoid expansion under the solid lead and danger of cracking the container. Or the alternative may be used of running a small diameter wooden or metal rod to the bottom of the bath before setting it aside to solidify, so that a relief channel may be formed from top to bottom to take care of expansion when again fusing.

The retort can be taken apart while practically red hot and there is little temptation to use water on it for cooling. It is accessible for perfect cleaning and the cost is insignificant. As 1 in. of lead is equivalent to about 11 in. of water, a seal of an inch or two is enough for ordinary purposes, including collection of gas over mercury trough, potash bulbs and open scrubbers.

Crown Willamette Paper Co.,
Floriston, Cal.

Measuring Coke Oven Gas Used in Soaking Pits

INCREASING quantities of surplus gas from by-product coke oven plants are being consumed in various processes in steel mills and it is desirable to have an accurate and reliable measurement of this gas. For this purpose the Thomas meter has been applied, which measures the quantity of gas in standard units, such
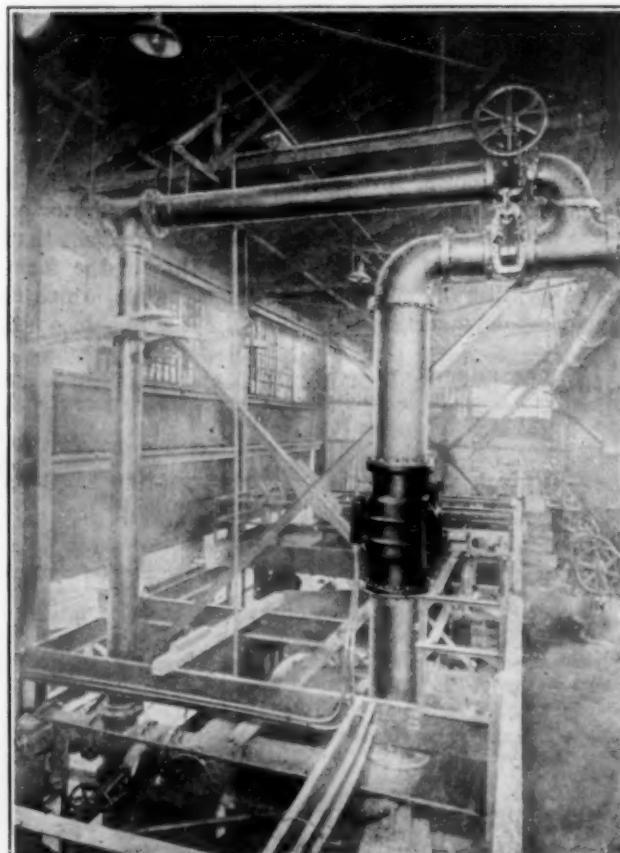

FIG. 1. HOUSING INSTALLATION, BRIER HILL STEEL CO.

as cubic feet at 30-60, without any calculations or corrections for pressure and temperature, although these may vary through wide ranges. The total quantities (in cubic feet) are shown on an integrating meter and the rate of flow is shown graphically on a curve drawing instrument. The graphic chart obtained from this instrument is very useful to the superintendent of a coke oven plant, showing him at a glance the amount of gas being used for fuel in the coke ovens over any period, with variations in quantities clearly indicated.

The meter is installed in a housing which replaces a portion of the gas pipe line as shown in the accompanying illustration of an installation at the Brier Hill Steel Company, Youngstown, Ohio. The principle of the Thomas meter is that it measures the heat capacity of a gas electrically. The amount of electric heat necessary to raise a standard unit two degrees is used as a measure of the gas flowing through the meter. The electricity for heating the gas can be conducted on comparatively small wires, consequently the meters showing the amount of gas used can be placed in the superintendent's office or other desired location, which may be several hundred feet from the meter proper.

The graphic chart shows him at a glance just how much gas is being used at any time in the soaking pit building. The complete Thomas meter and recording panels are made and installed by the Cutler-Hammer Manufacturing Company of Milwaukee, Wis.

The Cost in Coal of Avoidable Belt Slip

TO show the extent of the loss of money through slipping of the main belt alone a chart, supplied us through the courtesy of the Cling-Surface Company, Buffalo, N. Y., is shown herewith, upon which this is easily ascertained. By glancing up and down column "D" of this chart it is evident that the "cost of avoidable belt slip per year in dollars" may vary all the way from the smallest sums into the thousands of dollars.

Where the power in the first place is generated by a steam engine and is then transmitted to a generator or to the main shaft through a main belt it is evident that the "entire coal pile" passes through that in the form of energy, literally speaking. If the belt slips, which it should not do, a certain portion of the coal pile does not
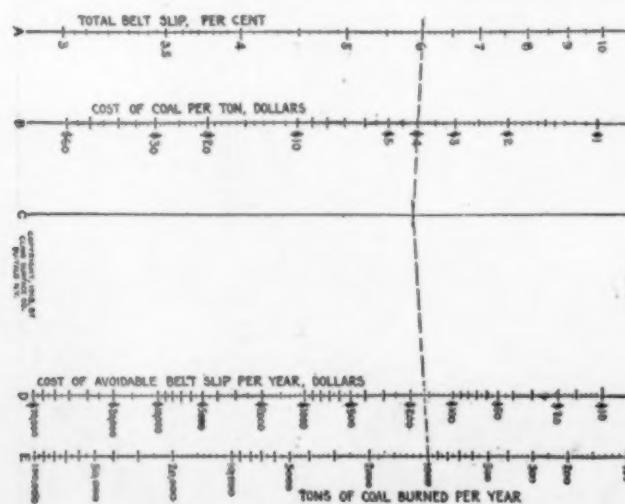
FIG. 1. CHART FOR DETERMINING COST OF BELT SLIP

"get through," but is lost into the atmosphere in the form of waste heat. A main belt is merely a "link" connecting the engine with the generator or with the machines themselves. In fact, every belt that transmits power is a connecting link and the efficiency of that link depends largely upon the freedom from slippage and the avoidance of strain on the shafts. Slipless, easy-running belts are most desirable.

To give a clear idea as to the meaning of "total belt slip per cent" take the following example: You find by means of a revolution counter that a given driven pulley is rotating only 940 times per minute. You figure that without slip it should rotate 1000 times per minute. Sixty revolutions per minute, therefore, are absolutely lost. Dividing this 60 by the r.p.m. that pulley should make you get 0.060, or 6 per cent, which is the "total belt slip." After having made this determination it is a simple matter to apply it to the chart and determine the money loss per year due to such slip.

Furthermore, belts which do not slip do not require tension and can be run easy or slack—every belt thus relieved of its tension reduces by that much the total plant friction load and this means also a longer-lived belt, cool bearings, less oil used, less time of men and machines lost during repairs and more power at the machines, for friction represents lost power.

A New End-Suction Centrifugal Pump

A new design of centrifugal pump manufactured by the Wheeler Condenser & Engineering Company, Carteret, N. J., is of special interest because of the unusual position of the suction opening. This opening, it will be noted, is directly beneath and parallel to the end bearing. In this position it is out of the way, yet it is in a convenient place for the erection men, for inspection, for upkeep, etc.

This arrangement makes it possible to place a pumping unit in a room of small ground area—considerably
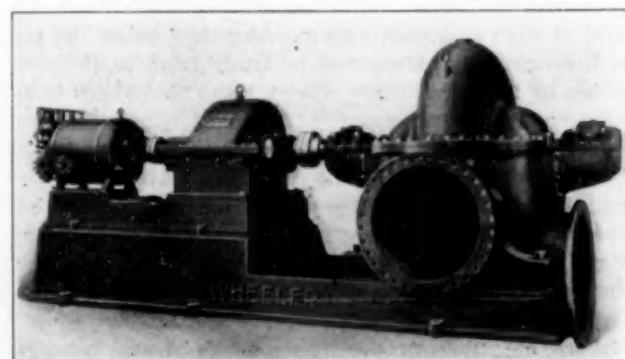
FIG. 1.   ASSEMBLED VIEW OF END-SUCTION PUMP

smaller than where the suction end is opposite the outlet end, as is the most common practice. In many cases this also facilitates the making of pipe connections, saving elbows and reducing the length of piping.

The capacity of the particular pump shown is 45,000 gal. per min. against a head of 20 ft. The diameter of the outlet pipe is 36 inches. The speed of the pump is 240 r.p.m. and is coupled by a 10 to 1 reduction gear to a steam turbine, whose speed is 2400 r.p.m.

Personal

Messrs. G. W. AKERLOW and J. M. LUNDQUIST have opened an office as consulting and mechanical engineers in Denver. They will handle mill design, special machinery and oil shale refining plants.

Mr. WATSON BAIN, professor of applied chemistry at the University of Toronto, has been granted leave of absence for the duration of the war. He is going to Washington, D. C., where he will be on the staff of the Canadian mission.

Dr. JOHN E. BUCHER, professor of chemistry in Brown University, has been granted leave of absence for the second semester of the academic year, in order to devote himself to experimentation in chemical processes in the industry. He will continue to direct the work of certain advanced students in the university laboratory, but will be relieved of all teaching during the remainder of the year. Dr. Robert F. Chambers, a Brown graduate, will be acting head of the department during the second semester.

Mr. W. C. CAPRON has been advanced from the position of assistant chief engineer of the Washoe Reduction Works to that of mechanical superintendent of the same plant. A number of other changes in the engineering staff of the Anaconda Copper Mining Company have followed this change. Mr. C. D. WOODWARD has been transferred from assistant chief engineer of the Great Falls reduction department in Butte, where he will be chief electrician of all the Anaconda properties in Montana. Mr. Woodward is succeeded in Great Falls by Mr. GEORGE TYRON, formerly chief draftsman of the Washoe Plant. Mr. H. W. RUTHERFORD, designer, becomes superintendent of construction for Stack, Cottrell Treaters and Arsenic Plant, Washoe Reduction Works, succeeding Mr. W. E. MEALS, who becomes chief draftsman.

Dr. F. E. CARRUTH, formerly connected with the chemical division of the North Carolina Experiment Station, has become associated with the Schaefer Alkaloid Works, Maywood, N. J.

Mr. E. R. CRUTCHER, superintendent of the Judge Smelter, Park City, Utah, has resigned and will go to South America. He is succeeded by J. F. ELLSWORTH.

Mr. A. A. HAWKES has been named to succeed J. M. GOETCHIUS as vice president and director of the General Chemical Co. Mr. GOETCHIUS resigned in order to give his services to the Government.

Mr. HERBERT LONGSTAFF has been appointed St. Louis manager for the Asbestos Protected Metal Co., of Pittsburgh, Pa.

The following changes and additions have recently been made in the sales organization of the Pfadler Co., Rochester, N. Y.: Mr. W. E. FOSTER now represents them as manager of the Atlantic Coast Sales Division; vice, F. L. CRADDOCK, with headquarters at the New York office, 110 West Fortieth Street. Mr. PHILIP S. BARNES, formerly with the Avery Chemical Company, of Lowell, Mass., is now associated with the sales department as consulting chemical engineer, with headquarters at the New York office. On April 1st the Chicago office will be removed from the Schiller Building, where it has been for a number of years, to 1442 Conway Building. Mr. R. B. KILMER is in charge.

Dr. C. L. REESE, of E. I. du Pont de Nemours & Co., has been named chairman of the committee on dyestuffs and intermediates of the Chemical Alliance.

Mr. H. D. SAVAGE, manager of sales, has been elected vice president of the Locomotive Pulverized Fuel Company. He will also continue as vice president of the American Arch Company.

Mr. LEWIS SEARING, of the Denver Engineering Works Co., has sold his half interest in the Denver Engineering Works Co. to the Hardinge Conical Mill Co. Mr. Searing will terminate his connection with the company on June 1.

Dr. WILLIAM P. WOOD, assistant professor of chemical engineering at the University of Michigan, has resigned, to join the Signal Corps of the Army.

Current Market Reports

The Iron and Steel Market

There has been no revival of activity in the pig iron and finished steel markets since the reaffirmation of prices for another three months, to July 1, with slight revisions in pig iron and scrap prices. There was no particular reason to suppose that the market would increase in activity. There is heavy Government buying, heavier perhaps than early in the year, but this is not considered market activity, all such buying being practically in the form of allotments.

As to commercial steel buying, it is to be borne in mind that the steel mills are carrying on their books more than 12,000,000 tons of purely commercial business, entirely apart from war orders, direct from the Government, or indirect. These obligations represent something like normal requirements of regular buyers, chiefly jobbers and manufacturing consumers. These buyers have no occasion to enter into additional engagements, for distant deliveries, as conditions are not such as to enable them to gage their consumptive requirements far in advance. The incentives to forward buying that frequently exist are altogether absent now. There is no definite prospect of there being higher prices in future. There is no particular advantage in buying early to secure a place on order books as deliveries will be regulated by Government requirements and the Government's views as to the usefulness of the buyer's industrial operations. There may be lower prices fixed by the Government, in which case the buyer is protected, but the Government edict in this respect does not cover the buyer against declines in the open market, below the set prices, produced by open competition, and of such competitive selling there is a distinct possibility.

An additional cause for the dullness in the open market is the fact that new projects are lacking. The commercial requirements in steel, such as they are, come from regular buyers, who are already covered, and do not hinge upon new projects.

DELIVERIES MUCH HEAVIER

Transportation conditions have been steadily improving, and a double result follows. Shipments from mills are heavier, and material long delayed *en route* has been reaching the buyer, so that while shipments have increased, deliveries have increased still more. This is beginning to tell upon the situation, and the majority of buyers of finished steel products find themselves in much more comfortable position. It is quite possible that within a few weeks many buyers will request mills to reduce shipments.

Production of finished steel has not increased as much as shipments. At practically all mills in the past few weeks there has been a reduction of stocks accumulated in January and February, and in nearly all cases it is desired to reduce the stocks greatly, as much of the tonnage is sadly in the way, having accumulated by force of circumstances and not by design. Shipments of finished steel during the fore part of April may be estimated at about 90 per cent of capacity, and production at 80 to 85 per cent. Capacity having increased very materially of late, shipments are now at approximately the average rate that obtained in 1916, when the existing capacity was fully employed.

Pig iron production has increased very sharply in the past few weeks, from a rate of 25,000,000 tons a year or thereabouts in the early part of February to a present rate of close to 40,000,000 tons. The greatest production in a calendar year has been 39,400,000 tons, in 1916, while through the completion of 17 new furnaces since 1916 capacity at present is about 43,000,000 tons.

There remains some shortage of coke, but only in spots. Shipments of Connellsville coke have greatly increased and are now approximately equal to the requirements of the furnaces still tributary to the region. These requirements are materially less than formerly, by reason of the com-

pletion of so many by-product ovens, and further decreases are to occur as additional by-product ovens are completed. Since the beginning of 1917 by-product capacity has come in to the extent of about 4,500,000 tons a year, while new plants scheduled for completion within the next few months will add fully 6,500,000 tons more, making an addition of considerably more than 10,000,000 tons since the end of 1916, yet in 1916 there was coke sufficient for the production of 39,400,000 tons of pig iron, and the present blast furnace capacity, as just noted, is only about 43,000,000 tons. While Connellsville coke sold at $10 to $15 a ton before the Government set the price at $6, it is quite possible that coke will eventually seek a market at much below the Government limit.

PRICES IN FUTURE

The only changes made in prices to rule from April 1 to June 30 were a reduction of $1 a ton in basic iron and reductions of $1 a ton in all descriptions of scrap upon which prices had been fixed. Basic iron dropped from $33 to $32, at furnace, and this brought Bessemer down from $36.30 to $35.20, as Bessemer is set at 10 per cent above basic.

It was made clear by the War Industries Board that the chief reason a general reduction in steel prices was not sought at the conference late in March was that the producers had had a hard time in the winter, with very irregular operations and consequently particularly high costs. The board's idea seemed to be to give the industry three months time without change in prices, and then consider conditions afresh. With the much steadier operations now possible costs are bound to decrease, although it is to be noted that wages were advanced about 10 per cent, effective October 1, just after the original price agreement was reached, and April 15 an additional advance of about 15 per cent becomes effective. Wages will then be very nearly double what they were in 1915, and almost triple what they were in 1898, as a result of five years of industrial depression.

On the one hand there is a distinct possibility of general, though not great, reductions in iron and steel prices July 1, by action of the Government, while on the other hand there are distinct possibilities of market declines through open competition, it being quite clear that all war requirements combined can hardly engage more than one-half the total productive capacity, while the strictly peace demand that remains can hardly be expected to absorb the other half. At the same time the general attitude of producers is that the set Government prices, prescribed as maximum, should in the general interest be regarded as minimum likewise.

For the long future, it is becoming clearer week by week that no return to former costs in the iron and steel industry is to be expected. Labor is on a different basis, and working conditions in the industry must be made such as to attract native born labor. Steel prices after the war may be, and probably will be, lower than at present, but no return to levels obtaining previous to the war can possibly be expected in view of conditions as they have lately been shaping themselves.

Non-Ferrous Metal Market

Monday, April 8—There has been practically no change in the tin situation and copper is moving steadily with demands being fairly well taken care of. The lead situation has eased up considerably and supplies are plentiful. Spelter continues weak.

Copper — Transportation facilities have improved and fewer delays have resulted. Consumers are being well supplied at present and although the demand from the Government and the Allies is expected to be increasingly heavy, the producers are expected to be able to meet them. The price remains at 23.50c. for producers and 24.67½c. for jobbers. Smelter production is estimated at 200,000,000 lb. per month.

Tin—Spot stocks are very low and few supplies are for sale. The market is very difficult and while it is not impossible to pick up small odd lots here and there, they are

very scarce and are 99 per cent material. China is about the only source of supply at present and spot is held at around 90 cents with futures at 80 cents.

Lead—Lead is slightly lower and has sold in the New York market for from 7 to 7¼ cents. In E. St. Louis the price has been 6.90 to 7.17½ cents. The large producers are well sold up but supplies have been more freely offered by the small producers.

Spelter—Spelter continues to decline and has dropped to 6.90 to 7.00 cents E. St. Louis and 7¼ cents New York. The lower price will probably further decrease production.

OTHER METALS

Aluminium, lb., 98-99 per cent, virgin, Gov't price...	.32
Bismuth, lb. ...	2.50-2.75
Cadmium, lb. ...	1.40
Nickel, electrolytic, lb. ...	.55
Silver, oz. ...	.91½
Platinum, oz. ...	108.00
Palladium, oz. ...	150.00
Cobalt, lb. ...	3.25-3.50
Magnesium, lb. ...	2.00
Quicksilver, Cal. ...	120.00
Quicksilver, Mexican ...	115.00

Chemical Market

COAL TAR PRODUCTS: The market was particularly quiet in most of the important items during the interval. Prices were somewhat easier in the crudes, due to the more liberal offerings and the falling off in the demand.

Benzol: The demand is confined mostly to spot material, but there is a fair volume of business passing on contract over short terms. It is said that some large contracts have been closed at a concession.

Toluol: Some large quantities have been released by the governmental authorities of late, for use in intermediates and dyes. The government appears to be determined not to permit offerings on the open market, although there are small quantities available from time to time.

Phenol: Offerings have been considerably augmented and with the demand quiet prices are slightly easier.

Naphthaline: While the demand is not pressing, offerings are light and prices are fairly well maintained.

Aniline Oil: The demand has been quite active of late and though there are resale lots available at a concession in price, producers are quite firm in their ideas.

Beta Naphthol: There has been an active demand for the technical material, but prices have held steady and unchanged, as there are large quantities available.

Benzoate of Soda: The consuming demand has not, as yet, been heavy, and, though there is some fluctuation in price, in general the position is unchanged.

Phthalic Anhydride: Some of the important factors are energetically endeavoring to secure business, and prices have depreciated under the strong competition in the market.

H. Acid: There are large quantities on the market, with the demand more or less routine and prices unchanged.

Resorcin: Considerable competition has developed and with only a moderate demand prevailing prices are easier.

Salicylic Acid: Is weak with the demand light because of inability to secure export licenses.

Sulphanilic Acid: Is not in heavy demand, but there are only a few producers and prices are unchanged.

Benzyl Chloride: There are only a few producers offering at present because of the scarcity of toluol, and prices are inclined higher.

Benzidine Base: Is only fairly active and prices are unchanged with a moderate production.

HEAVY CHEMICALS: The feature of the market during the past two weeks has been the recovery of caustic soda from the low point recorded in our last issue. Material shipped to this point had accumulated to such an extent that pressure was brought on owners with view to releasing cars and as a consequence caustic was offered at concessions. Aside from this movement the market has been quiet and the trade has as a rule been disappointed with the amount of trading that has come to hand.

Caustic Soda: From a price of below 4c., the market has

advanced to the 5c., level with trading noted at this figure spot and contracts closed basis works freight as high as 5½c. Several important consumers have entered the market of late and in addition to this several of the producers have been buyers with the result that the market has presented more activity than at any period since last October when the famous slump occurred. The spot market has been fairly well cleaned up and offers have been rather restricted of late with the producers well in control of the situation once more. An interesting feature of the market during the fortnight was the announcement of several producers who are now quoting 3½c. basis 60% works for 1919 business. This price is considered high by consumers but producers claim the increased cost of labor, coal, lime and other incidentals warrants such a level. Business is reported to have passed at the level mentioned.

Soda Ash: This market did not respond to the upward trend in caustic until the past few days when an active inquiry developed for barrels and after a low period of selling the market advanced again to 3.10 and 3.15 f.a.s. The inquiry of late has been principally for export barrels. Bags have been neglected with trading at from 2.50 to 2.60. Dense ash has been tight at 3.75 double bags New York.

Copper Sulphate: Resales have depressed what should in the ordinary course of events be a rising market. Nichols 98/99% large crystals have sold as low as 8.50 although business has passed at 9c. and perhaps a trifle higher from certain quarters.

Cyanide of Soda: Some buying has been reported and the market was at one time up to 40c., but at the moment of writing 38c. can be done for domestic material.

Acetic Acid: This has been one of the features of the chemical market. Sales have occurred at such a wide variance that prices mean nothing. Locating supplies seems to be the main accomplishment and a consumer will pay most any price the seller demands. Prices really mean nothing as they change from hour to hour.

Sulphuric Acid: An easier feeling has prevailed owing to the fact that quite a few cars of 66 brimstone acid have appeared on the market ranging in price from $35.00 upward. Even at these prices buyers have not appeared interested. Sixty degree material has been offered at $25.00 sellers tanks works. Sixty-six brimstone acid is held at $40.00 drums works.

Oleum: This market has followed sulphuric and resales have been made at $70.00 drums and $65.00 tanks works.

Nitric Acid: As a result of the strong nitrate of soda situation the market is firmer and resale material at 8¾c. has been eliminated and little under 9c. can now be obtained.

Nitrate of Soda: Definite word from the government fixing the price at which nitrate of soda may be sold is expected. In the meanwhile the government frowns in resales but these have been occurring at prices ranging from 5.20 upward at various points. The market looks rather uncertain with a probability of higher prices.

Aqua Ammonia: Despite the government's desires there has been considerable trading but the trade is rather inclined to go slow and prices are somewhat lower than when last reported. Business has passed in 26 degree material at 25c. to 27c.

Sodium Nitrite: No particular activity is noted and resales have occurred at 33c. to 35c. A new producer offers contracts at 30c. f.o.b. works.

Bichromate of Soda: The market has been manipulated to a pronounced extent and short interests have been covering whenever possible without risking too much of an advancing market. Sales have occurred between 22c. and 25c., spot and works, and there is no telling what may happen from day to day.

Citric Acid: This has been probably the most fluctuating item in the chemical trade during the interval. An advance of 22 points was scored in one day. The product sold as high as $1.00 but at the moment of writing domestic material is available at 88c.

Acetic Anhydride: Consumers working on government

requirements may secure material at $1.15 but outside consumers are compelled to pay from $1.50 to $1.60 for spot supplies.

General Chemicals

WHOLESALE PRICES IN NEW YORK MARKET, APRIL 8, 1918

Acetic anhydride	lb.	1.35	—	1.50
Acetone, drums	lb.		Nominal	
Acid, acetic, 28 per cent	lb.	.09	—	.11
Acetic, 56 per cent	lb.	.19	—	.20
Acetic, glacial, 99½ per cent., carboys	lb.	.37	—	.38
Boric, crystals	lb.	.13½	—	.14½
Citric, crystals	lb.	.88	—	.90
Hydrochloric, C. P.	lb.	.08	—	.08½
Hydrochloric, 20 deg.	lb.	.02½	—	.02½
Hydrochloric, conc., 22 deg.	lb.	.02½	—	.03
Hydrofluoric, 30 per cent., in barrels	lb.	.06	—	.06½
Lactic, 44 per cent	lb.	.13	—	.15
Lactic, 22 per cent	lb.	.05½	—	.06½
Nitric, 36 deg	lb.	.08½	—	.08½
Nitric, 42 deg	lb.	.09	—	.09½
Oxalic, crystals	lb.	.44	—	.45
Phosphoric, 47.50 per cent. paste	lb.	.08	—	.10
Phosphoric, ref. 50 per cent	lb.	.26	—	
Picric	lb.		Nominal	
Pyrogallic, resublimed	lb.	3.10	—	3.15
Sulphuric, 60 deg	ton	25.00	—	27.50
Sulphuric, 66 deg	ton	40.00	—	45.00
Sulphuric, oleum (Fuming), tank cars	ton	60.00	—	75.00
Tannic, U. S. P., bulk	lb.	1.30	—	1.35
Tartaric, crystals	lb.	.75	—	.78
Tungstic, per lb. of W	lb.	1.80	—	1.90
Alcohol, sugar cane, 188 proof	gal.	4.93	—	4.95
Alcohol, wood, 95 per cent	gal.	.90½	—	.91
Alcohol, denatured, 180 proof	gal.	.68	—	.69
Alum, ammonia lump	lb.	.04	—	.04½
Alum, chrome ammonium	lb.	.18	—	.19
Alum, chrome potassium	lb.	.19	—	.20
Alum, chrome sodium	lb.	.12½	—	.13
Alum, potash lump	lb.	.09	—	.09½
Aluminium sulphate, technical	lb.	.02	—	.02½
Aluminium sulphate, iron free	lb.	.03½	—	.03½
Ammonia aqua, 26 deg. carboys	lb.	.25	—	.26
Ammonia, anhydrous	lb.		Nominal	
Ammonium carbonate	lb.	.11	—	.12
Ammonium nitrate	lb.	(Fixed price)		.14
Ammonium, sulphate domestic	lb.	.07½	—	.08
Amyl acetate	gal.	5.00	—	5.25
Arsenic, white	lb.	.16½	—	.17½
Arsenic, red	lb.	.65	—	.70
Barium carbonate, 99 per cent	ton	80.00	—	90.00
Barium carbonate, 97-98 per cent	ton	65.00	—	67.00
Barium chloride	ton	65.00	—	85.00
Barium sulphate (Blanc Fixe, powder)	lb.	.03½	—	.04
Barium nitrate	lb.	.09½	—	.10
Barium peroxide, basis 70 per cent	lb.	.30	—	.32
Bleaching powder, 35 per cent chlorine	lb.	.02½	—	.02½
Borax, crystals, sacks	lb.	.07½	—	.08½
Brimstone, crude	ton		Nominal	
Bromine, technical	lb.	.75	—	....
Calcium, acetate, crude	lb.		Nominal	
Calcium, carbide	lb.	.13	—	.14
Calcium chloride, 70-75 per cent., fused, lump	ton	27.50	—	30.00
Calcium peroxide	lb.	1.60	—	1.70
Calcium phosphate	lb.	.34	—	.35
Calcium sulphate 98-99 per cent	lb.	.09	—	.09½
Carbon bisulphide	lb.	.08	—	.10
Carbon tetrachloride, drums	lb.	.15½	—	.16
Carbonyl chloride (phosgene)	lb.	1.10	—	1.50
Caustic potash, 88-92 per cent	lb.	.84	—	.85
Caustic soda, 76 per cent	lb.	.05	—	.05½
Chlorine, liquid	lb.	.15	—	.18
Cobalt oxide	lb.	1.60	—	1.65
Copperas	lb.	.01½	—	.01½
Copper carbonate	lb.	.30	—	.40
Copper cyanide	lb.	.75	—	.78
Copper sulphate, 99 per cent., large crystals	lb.	.08½	—	.09½
Cream of tartar, crystals	lb.	.58	—	.60
Epsom salt, bags, U.S.P.	lb.	.03½	—	.03½
Formaldehyde, 40 per cent	lb.	.19½	—	.20
Glauber's salt	190 lb.	1.50	—	2.00
Glycerine, bulk, C. P.	lb.	.68½	—	.69
Iodine, resublimed	lb.	4.25	—	4.35
Iron oxide	lb.	.13	—	.15
Lead, acetate, white crystals	lb.	.17	—	.18
Lead arsenate (Paste)	lb.	.15	—	.18
Lead nitrate	lb.	.15	—	.16
Litharge, American	lb.	.09½	—	.11½
Lithium carbonate	lb.	1.50	—	2.00
Manganese dioxide, U. S. P.	lb.	.70	—	.75
Magnesium carbonate, technical	lb.	.10½	—	.11
Nickel salt, single	lb.	.14	—	.15
Nickel salt, double	lb.	.12	—	.14
Phosgene, see Carbonyl chloride				
Phosphorus, red	lb.	1.30	—	1.50
Phosphorus, yellow	lb.	1.50	—	1.60
Potassium bichromate	lb.	.44	—	.46
Potassium bromide granular	lb.	1.35	—	1.50
Potassium carbonate calcined, 85-90 per cent	lb.	.95	—	1.05
Potassium chlorate, crystals	lb.	.36	—	.40
Potassium cyanide, 98-99 per cent	lb.		Nominal	
Potassium iodide	lb.	3.75	—	3.80
Potassium muriate 80-85 p. c. basis of 80 p. c.	ton	340.00	—	350.00
Potassium nitrate	lb.	.27	—	.31
Potassium permanganate (U. S.P.)	lb.	4.00	—	4.10
Potassium prussiate, red	lb.	2.80	—	2.90
Potassium prussiate, yellow	lb.	1.20	—	1.25
Potassium sulphate, 90-95 p. c. basis 90 p. c.	ton		Nominal	
Rochelle salts	lb.	.40	—	.42
Salammoniac, gray gran	lb.	.16	—	.17
Salammoniac, white gran	lb.	.15½	—	.16
Sal soda	100 lb.	1.35	—	1.40
Salt cake	ton	24.00	—	27.00
Silver cyanide, based on market price of silver	oz.	...	—	...
Silver nitrate	oz.	.59½	—	.60½

Soda ash, 58 per cent., light, flat	100 lb.	2.60 —	2.70
Soda ash, 58 per cent., dense, flat	100 lb.	3.75 —	.....
Sodium acetate	lb.	.23 —	.24
Sodium bicarbonate, domestic	lb.	.02½ —	.03
Sodium bicarbonate, English	lb.		
Sodium bichromate	lb.	.22½ —	.23
Sodium bisulphite, powd.	lb.	.05½ —	.06
Sodium chlorate	lb.	.24 —	.25
Sodium cyanide	lb.	.38 —	.40
Sodium fluoride, commercial	lb.	.17 —	.18
Sodium hyposulphite	lb.	.02½ —	.....
Sodium molybdate, per lb. of Mo	lb.	2.50 —	.....
Sodium nitrate, 95%	100 lb.	Nominal	
Sodium nitrate	lb.	.33 —	.34
Sodium peroxide	lb.	.50 —	.52
Sodium phosphate	lb.	.04 —	.05
Sodium prussiate, yellow	lb.	.39 —	.40
Sodium silicate, liquid (60 deg.)	lb.	.04½ —	.05
Sodium sulphide, 30 per cent., crystals	lb.	.02½ —	.03
Sodium sulphide, 60 per cent., fused	lb.	.05 —	.05½
Sodium sulphite	lb.	Nominal	
Strontium nitrate	lb.	.25 —	.35
Sulphur chloride, drums	lb.	.06 —	.06½
Sulphur dioxide, liquid, in cylinders	lb.	.15 —	.40
Sulphur, flowers, sublimed	100 lb.	4.05 —	4.60
Sulphur, roll	100 lb.	3.70 —	3.85
Sulphur, crude	ton	Nominal	
Tin bichloride, 50 deg.	lb.	.23½ —	.24½
Tin oxide	lb.	.78 —	.80
Zinc carbonate	lb.	.25 —	.30
Zinc chloride	lb.	.12½ —	.13
Zinc cyanide	lb.	Nominal	
Zinc dust, 350 mesh	lb.	.14 —	.16
Zinc oxide, American process XX	lb.	.14 —	.15
Zinc sulphate	lb.	.06 —	.07

Coal Tar Products (Crude)

Bensol, pure, water white	gal.	.30 —	.35
Bensol, 90 per cent.	gal.	.....	.....
Toluol, pure water white	gal.	Nominal	
Xylol, pure, water white	gal.	.35 —	.50
Solvent naphtha, water white	gal.	.17 —	.22
Solvent naphtha, crude, heavy	gal.	.13 —	.16
Creosote oil, 25 per cent.	gal.	.33 —	.35
Dip oil, 20 per cent.	gal.	.29 —	.30
Pitch, various grades	ton	8.00 —	20.00
Carbolic acid, crude, 95-97 per cent.	lb.	1.05 —	1.10
Carbolic acid, crude, 50 per cent.	lb.	.60 —	.65
Carbolic acid, crude, 25 per cent.	lb.	.35 —	.38
Cresol, U. S. P.	lb.	.18 —	.20

Intermediates, Etc.

Alpha naphthol, crude	lb.	1.00 —	1.25
Alpha naphthol, distilled	lb.	1.60 —	2.00
Alpha naphthylamine	lb.	.58 —	.60
Aniline oil, drums extra	lb.	.25½ —	.27
Aniline salts	lb.	.32 —	.34
Anthracene, 80 per cent.	lb.	.50 —	.65
Benzaldehyde (f.f.c.)	lb.	5.00 —	5.50
Benzidine, base	lb.	1.75 —	1.85
Benzidine, sulphate	lb.	1.40 —	1.50
Benzoic acid U. S. P.	lb.	4.25 —	4.50
Benzoate of Soda, U. S. P.	lb.	4.00 —	4.25
Benzyl chloride	lb.	2.25 —	2.50
Beta naphthol benzoate	lb.	10.00 —	12.00
Beta naphthol, sublimed	lb.	.85 —	.90
Beta naphthylamine, sublimed	lb.	2.65 —	.....
Dichlor benzol	lb.	.12 —	.18
Diethylaniline	lb.	4.00 —	5.00
Dinitro benzol	lb.	.35 —	.40
Dinitrochlorbenzol	lb.	.40 —	.42
Dinitronaphthaline	lb.	.55 —	.60
Dinitrotoluol	lb.	.55 —	.60
Dinitrophenol	lb.	.46 —	.50
Dimethylaniline	lb.	.65 —	.70
Diphenylamine	lb.	1.00 —	1.10
H-acid	lb.	2.25 —	2.50
Metaphenylenediamine	lb.	2.00 —	2.25
Monochlorbenzol	lb.	.19 —	.22
Naphthalene, flake	lb.	.10½ —	.10½
Naphthalene, balls	lb.	.12 —	.14
Naphthionic acid, crude	lb.	1.20 —	1.30
Naphthylamin-di-sulphonic acid	lb.	1.00 —	1.10
Nitro naphthaline	lb.	.45 —	.50
Nitro toluol	lb.	.50 —	.55
Ortho-amidophenol	lb.	.....	.....
Ortho-dichlor-benzol	lb.	.15 —	.18
Ortho-toluidine	lb.	1.25 —	1.30
Ortho-nitro-toluol	lb.	.75 —	1.00
Para-amidophenol, base	lb.	3.50 —	3.75
Para-amido-phenol, H. Ch.	lb.	4.00 —	5.00
Para-dichlor-benzol	lb.	.12 —	.15
Paranitraniline	lb.	1.25 —	1.30
Para-nitro-toluol	lb.	1.50 —	1.60
Paraphenylenediamine (base)	lb.	3.00 —	3.25
Para toluidine	lb.	2.25 —	2.50
Phthalic acid anhydride	lb.	3.50 —	4.00
Phenol, U. S. P.	lb.	.53 —	.54
Resorcin, technical	lb.	5.75 —	6.00
Resorcin, pure	lb.	8.50 —	9.00
Salicylic acid	lb.	1.00 —	1.10
Salol	lb.	1.85 —	2.00
Sulphanilic acid, crude	lb.	.32 —	.35
Tolidin	lb.	2.50 —	.....
Toluidine-mixture	lb.	.75 —	.85

Petroleum Oils

Crude (at the Wells)

Pennsylvania	bbl.	4.00 —	.....
Corning, Ohio	bbl.	2.85 —	.....
Somerset, Ky.	bbl.	2.60 —	.....
Wooster, Ohio	bbl.	2.58 —	.....
Indiana	bbl.	2.18 —	.....
Illinois	bbl.	2.32 —	.....
Oklahoma and Kansas	bbl.	2.25 —	.....
Caddo, La., light	bbl.	2.25 —	.....

Corsicana, Tex., light	bbl.	2.35 —	.....
California	bbl.	.98 —	1.32
Gulf Coast	bbl.	1.35 —	.....

Fuel Oil

New York	gal.	.11 —	.....
Pittsburgh	gal.	.07½ —	.10
Oklahoma-Kans.	bbl.	1.05 —	2.75
Texas	bbl.	1.50 —	1.90
Los Angeles	bbl.	1.52 —	.....
San Francisco	bbl.	1.45 —	.....

Gasoline (Wholesale)

New York	gal.	.24 —	.....
Boston	gal.	.25 —	.....
Pittsburgh	gal.	.27 —	.....
Chicago	gal.	.21 —	.....
Oklahoma	gal.	.25 —	.....
San Francisco	gal.	.20 —	.....

Lubricants

Black, reduced, 29 gravity, 25-30 cold test	gal.	.21 —	.22
Cylinder, light	gal.	.36 —	.38
Cylinder, dark	gal.	.35 —	.36
Paraffine, high viscosity	gal.	.40 —	.41
Paraffine, .903 sp. gr.	gal.	.36 —	.38
Paraffine, .865 sp. gr.	gal.	.26 —	.28

Flotation Oils

(Prices at New York unless otherwise stated)

Pine oil, crude, f.o.b. Florida	gal.	.44 —	.....
Pine oil, steam distilled, sp. gr. 0.925-0.940	gal.	.53 —	.....
Pine oil, destructively diatilled	gal.	.49 —	.53
Pine-tar oil, sp. gr. 1.025-1.035	gal.	.35 —	.....
Pine-tar oil, double refined, sp. gr. 0.965-0.990	gal.	.40 —	.....
Pine oil, light, sp. gr. 0.950, tank cars, f. o. b. works	gal.	.37 —	.....
Pine oil, heavy, sp. gr. 1.025, tank cars, f. o. b. works	gal.	.26 —	.....
Pine tar, thin, sp. gr. 1.060-1.080	gal.	.30 —	.....
Turpentine, crude, sp. gr. 0.980-1.000	gal.	.40 —	.....
Hardwood oil, f. o. b. Michigan, sp. gr. 0.960-0.990	gal.	.19 —	.....
Hardwood oil, f. o. b. Michigan, sp. gr. 1.06-1.08	gal.	.19 —	.....
Wood creosote, ref. f. o. b. Florida	gal.	.31 —	.....

Vegetable and Other Oils

China wood oil	lb.	.23 —	.24
Cottonseed oil, crude	lb.	.17½ —	.18
Linseed oil, raw, cars	gal.	1.55 —	1.57
Peanut oil, crude	gal.	1.37 —	.....
Rosin oil, first run	gal.	.41 —	.....
Rosin oil, fourth run	gal.	.58 —	.....
Soya bean oil, Manchuria	lb.	.19 —	.19½
Turpentine, spirits	gal.	.41 —	.....

Miscellaneous Materials

Barytes, floated, white, foreign	ton	Nominal	
Barytes, floated, white, domestic	ton	30.00 —	36.00
Beeswax, white, pure	lb.	.56 —	.64
Casein	lb.	.22 —	.30
Chalk, light, precipitated, English	lb.		
China clay, imported, lump	ton	17.50 —	36.00
China clay, domestic, lump	ton	12.50 —	20.00
Feldspar	ton	8.00 —	12.00
Fuller's earth, powdered	100 lb.	1.00 —	1.50
Graphite, flake	lb.	.15 —	.18
Ozokerite, crude, brown	lb.	.65 —	.75
Ozokerite, American, refined, white	lb.	.75 —	1.00
Red lead, dry, carloads	lb.	.10 —	.11½
Rosin, 280 lb.	bbl.	6.15 —	.....
Soapstone	ton	10.00 —	12.50
Talc, American, white	ton	15.00 —	22.00
White lead, dry	lb.	.09 —	.10

Refractories, Etc.

(F.O.B. Works)

Chrome brick	net ton	Nominal	
Chrome cement, Grecian	net ton	Nominal	
Clay brick, 1st quality fireclay	per 1000	50.00 —	55.00
Clay brick, second quality	per 1000	35.00 —	40.00
Magnesite, raw	ton	30.00 —	35.00
Magnesite, calcined	ton	32.00 —	35.00
Magnesite, Grecian, dead burned	net ton	85.00 —	90.00
Magnesia brick, Grecian, 9x4½x2½	net ton	135.00 —	140.00
Silica brick	per 1000	50.00 —	60.00

Ferroalloys

Ferrocarbontitanium, 15-18 per cent., carloads, f.o.b. Niagara Falls, N. Y.	ton	200.00 —	.....
Ferrocerium	lb.	18.00 —	.....
Ferrochromium, per lb. of Cr	lb.	.50 —	.....
Ferromanganese, domestic, 80 per cent	ton	250.00 —	275.00
Ferromanganese, English	ton	325.00 —	.....
Ferromolybdenum, per lb. of Mo	lb.	5.00 —	.....
Ferrosilicon, 75 per cent., f.o.b. N. Y.	ton		
Ferrosilicon, 50 per cent., carloads, del., Pittsburgh	ton	180.00 —	190.00
Ferrosilicon, 50 per cent., contract	ton	100.00 —	175.00
Ferrotungsten, 75-85 per cent., f.o.b. Pittsburgh	lb.	2.25 —	2.35
Ferrouranium, f.o.b. works, per lb. of U	lb.	7.00 —	7.50
Ferrovanadium, f.o.b. works	lb.	4.00 —	5.00

Ores and Semi-finished Products

Antimony ore, per unit		1.60 —	1.75
Chrome ore, 48 per cent. minimum, f.o.b. Cal., per unit	ton	1.50 —	1.75
Chrome ore, 43 per cent. and over, New York, per unit	ton	1.50 —	.....
Manganese ore, 48 per cent. and over, per unit	ton	1.20 —	.....
Manganese ore, chemical	ton	80.00 —	100.00
Molybdenite, per lb. of MoS₂	lb.	1.80 —	.....
Tungsten, Scheelite, per unit of WO₃	ton	20.00 —	24.50
Tungsten, Wolframite, per unit of WO₃	ton	20.00 —	24.00
Uranium oxide, 96%	lb.	3.25 —	3.60
Vanadium pentoxide, 99%	lb.	10.50 —	.....
Pyrites, foreign	unit	.17 —	.17½
Pyrites, domestic	unit	.28 —	.30

INDUSTRIAL

Financial, Construction and Manufacturers' News

Construction and Operation

ALABAMA

BIRMINGHAM.—The National Steel Products Company is making rapid progress in the erection of a large new local plant to be devoted to the manufacture of steel castings. At the recent meeting of the board of directors, E. M. Kilby, who is vice-president of the Kilby Frog & Switch Company, was elected president of the National company.

ARIZONA

CHLORIDE.—The Hackberry Consolidated Mining Company is considering plans for the construction of a new mill for the treatment of its lead-zinc ore. The company is engaging in extensive development work at its properties.

COLORADO SPRINGS.—Poston & Blumfield have recently acquired extensive copper properties in the Squaw Peak district, near Clarksdale, and are planning for early development.

PRESCOTT.—The Copper Valley Mining Company, recently incorporated, and which acquired the Ehle claims in Skull Valley, has commenced development work, and it is said the company is contemplating the erection of a mill.

TOMBSTONE.—The Broskaw Mining Company is making rapid progress in the installation of compressors and other mining machinery at its properties. The company is considering plans for the construction of a new mill for the treatment of vanadium ore.

TUCSON.—The Pima Smelter & Refining Company, recently incorporated with a capital of $1,000,000, is planning for the removal of its furnace plant now in operation at Socorro, New Mexico, to a site now under consideration near the city. The company has already placed orders for its converter equipment.

MAMMOTH.—The E. W. Childs molybdenite properties on Copper Creek, near Mammoth, have been taken over by new interests for a consideration said to be about $200,000, and extensive development work is planned. In the past, the milling of the ore has been considered rather difficult, due to its copper contents, but it is planned to employ a new process whereby the copper will be eliminated by means of hydrochloric acid, and thereafter saved by electrostatic deposition, the molybdenum being left available for concentration by flotation.

ARKANSAS

HARRISON.—Ika Kilgore is having plans prepared for the construction of a new 100-ton concentrating mill for the handling of ores from nearby lead and zinc mines.

HOPE.—Operations have been inaugurated in the new plant of the Hope Fertilizer Company recently completed. It is planned to operate both the new and the old plants to supply the large demand for this product.

ROGERS.—M. F. Gurler, of Tulsa, Okla., and H. C. Holderman, Joplin, Mo., have leased approximately 2,000 acres of local property and are planning to develop the copper deposits.

RUSHE. E. L. Standley, operating a local plant for the manufacture of ore concentrating equipment, is planning for the establishment of a branch works at Yellville.

CALIFORNIA

FRESNO.—The San Joaquin Light & Power Corporation has made application to the State Water Supply Commission for permission to appropriate a water flow on the Kern River for a new hydroelectric power plant. The proposed station will have a capacity of about 20,000 horsepower, and is estimated to cost $1,000,000.

MARICOPA.—The Trojan Oil Company is making rapid progress in the construction of a large new refining and absorption plant for the extraction of gasoline from gas in the Aaktop field, near Calgary.

MARTINEZ.—The Butters Chemical Company is rushing to completion its new local electrolytic zinc plant, and it is expected that operations will soon be inaugurated.

MARTINEZ.—It is reported that huge additions will be made to the local plant of the Hercules Powder Company, including several additional nitric and sulphuric acid units, and seven more units for the manufacture of T.N.T. The company holds large contracts from both the Army and Navy Departments and it is understood that the new works will give employment to about 4000 hands.

OROVILLE.—The Western Ore Company is planning for the construction of a new concentration plant at its chrome claims at Lime Saddle, near Oroville.

SANTA ROSA.—The American Products Company has recently been organized to operate in Sonoma County, and will engage in the manufacture of printing inks and dyes.

COLORADO

DENVER.—The Queen City Foundry Company is planning for the immediate installation of a new one-ton Booth-Hall electric steel furnace, to replace the converter equipment now in use. The furnace which is rated at 300 kva., has a holding capacity of three-quarters to one ton. The Denver Gas & Electric Company will supply energy for the operation of the furnace.

GEORGETOWN.—The W. J. Chamberlain Ore Company has announced that it will close and dismantle its sampling works at Georgetown, Breckenridge and Blackhawk. It is said that the shutdown is due to the high cost of operation.

DELAWARE

DELAWARE CITY.—The United States Government, Ordnance Department, is said to be negotiating for the purchase of a large tract of land at Port Penn, near Delaware City, for the construction of a large new shell-loading plant. The plant will give employment to about 5000 hands.

WILMINGTON.—The E. I. duPont De-Nemours Company is planning for the manufacture of pipes and auxiliary equipment used in munitions works, in the plant of the B. F. Shaw Company, Second and Lombard Streets, recently acquired.

CONNECTICUT

FORESTVILLE.—A portion of the plant of the Bryce Manufacturing Company, Fredericks Street, manufacturer of ball bearings, etc., was recently destroyed by fire. The loss is estimated at about $50,000.

WATERBURY.—The American Brass Company has recently awarded a contract for the construction of a new one-story brick, steel and concrete addition to its plant, about 50 x 105 feet. The Sperry Engineering Company, New Haven, is the contractor.

GEORGIA

MACON.—Contract has been awarded by the Macon Gas Company for the construction of a new addition to its gas works to provide an increased capacity of approximately 10,600,000 cubic feet per month. The addition is estimated to cost $40,000, and is expected to be entirely completed by September 1. The Parker Russell Mining & Manufacturing Company, St. Louis, Mo., is the contractor.

IDAHO

KELTON.—The Mercher Mining Company is planning to inaugurate operations in its new 100-ton concentrating plant before the close of the month. This will also include flotation.

MURRAY.—The Miners Smelting & Refining Company has recently completed its organization plans and is contemplating the construction of a new plant on Coeur d'Alene Lake. C. T. Kennan, Murray, is interested in the company.

BOISE.—The Northwestern Development Company has commenced the operation of the Ranger copper claims, about twelve miles east of Salmon, Lemhi County. The company is considering plans for the construction of a large new concentrating plant.

ILLINOIS

CHICAGO.—J. L. Sparks, West Grand Avenue, is making rapid progress in the construction of a new one-story foundry, about 50 x 75 feet, at 1723 Carroll Avenue. The structure is estimated to cost $10,000.

CHICAGO.—The plant of the Phoenix Hermetic Company, manufacturer of glass jars, etc., was recently partially destroyed by fire, with loss estimated at $18,000.

CHICAGO.—A new one-story foundry, about 175 x 225 feet, is being erected at Hegewisch, Ill. by the Western Steel Car & Foundry Company, One Hundred and Thirty-sixth Street. The structure will cost $50,000.

CHICAGO.—The Illinois Steel Company has completed the erection of extensive additions to its Gary plant, including four additional furnaces, ore docks, rolling mills, and a Bessemer duplex plant. These mills are now the largest single unit of iron and steel producers in the world, and the plant has been increased by about fifty per cent since the war. The entire work is estimated to have cost approximately $20,000,000.

DECATUR.—The Leader Iron Works is making rapid progress in the construction of a new one-story addition to its plant, about 50 x 200 feet, to cost $10,000.

INDIANA

INDIANA HARBOR.—The Mark Manufacturing Company is planning to inaugurate operations in its new 80-inch plate mill at its North Harbor steel works at an early date. Construction work on other additions to the plant is progressing rapidly; the billet and blooming mills are expected to be completed within the next month, and the company will soon place in operation four open hearth blast furnaces. It is also expected to complete the construction of the coke ovens before the end of the year. About 4,000 hands will be employed for initial operations.

EAST CHICAGO.—The Green Engineering Company, South Kennedy Avenue, has had plans prepared for the construction of a new one-story foundry. The structure will be about 45 x 100 feet, and is estimated to cost $50,000.

IOWA

OTTUMWA.—The plant of the Morey Clay Products Company was partially destroyed by fire on March 19, with loss estimated at $25,000.

KENTUCKY

WINCHESTER.—The Ken-See Mineral Company, recently incorporated with a capital of $25,000, is planning for the development of fluorspar lands near Marion. The company will commence the installation of the necessary equipment at an early date. Fielding H. Yost is president.

LOUISIANA

LAKE CHARLES.—The Lambert Chemical Company, St. Louis, Mo., has broken ground for the construction of the first unit of a large new manufacturing plant. The company recently acquired a local tract having a frontage of 800 feet as a site for the location of the works.

NEW ORLEANS.—The E. Z. Opener Bag Company has acquired property fronting on Toulouse, Scott and Cortez Streets, about 120 x 329 feet, comprising five-story and four-story factory buildings and warehouse, and is planning for extensive improvements and the installation of new equipment to cost about $50,000, for the manufacture of paper bags. H. E. Westervelt is president.

NEW ORLEANS.—The United States Sulphur Company, Inc., has filed notice of a change in its corporate name to the American Brimstone Company, Inc.

SHREVEPORT.—The Equitable Window Glass Company, Buckhannon, W. Va., has taken over the plant of the National Window Glass Company, Cedar Grove, near Shreveport, for the establishment of a new manufacturing plant.

SHREVEPORT.—The Marine Oil & Refining Company is rushing to completion the erection of a new refinery at Cedar Grove, near Shreveport, and it is expected that operations will be inaugurated at an early date.

MASSACHUSETTS

CONCORD JUNCTION. — The plant of the Whitman & Pratt Rendering Company was recently totally destroyed by fire on March 21, with loss estimated at $150,000. A large quantity of fertilizer and many hundreds of cases of soap were also destroyed.

WORCESTER.—The Crompton & Knowles Loom Works, 93 Grand Street, have commenced the construction of a new one-story addition, about 55 x 185, at their plant. The structure is estimated to cost $20,000. E. D. Ward, 82 Foster Street, Worcester, is the contractor.

GREENDALE.—Fire, caused by an explosion, damaged the plant of the Shepard Manufacturing Company, manufacturer of ferrotype plates, to the extent of about $10,000, on March 28. The company had been engaged on some important work for the Government.

MICHIGAN

ALMA.—Operations have been inaugurated in the new local plant of the Ex-Cell-All Paint Company, and it is said that plans are under consideration for additions. The company was formerly located in Big Rapids and Marion.

DETROIT. — A new one-story plant, about 25 x 100 feet, will be erected by the General Aluminum & Brass Manufacturing Company, St. Aubin Street. The structure is estimated to cost $30,000. Contract has been awarded to the Austin Company, Cleveland, Ohio.

HOUGHTON.—The new 10,000 kw. power plant of Calumet & Hecla is rapidly nearing completion at its works on Lake Linden.

TWIN BRIDGES. — The Crystal Lake Mining Company is making rapid progress in the construction of a new concentrating mill at its properties.

MINNESOTA

BRAINERD.—The Brainerd Gas & Electric Company is planning for the construction of a new addition to its gas generating plant to cost about $10,000. It is planned to have the structure ready for operation by June 30.

ST. PAUL.—Plans are under consideration by the Gas Traction Foundry Company for the construction of a new one-story foundry, about 100 x 300 feet. The structure is estimated to cost about $65,000.

MISSOURI

ST. JOSEPH.—The plant of the Berry Foundry Company, Fifth and Oak Streets, was partially destroyed by fire recently, with loss estimated at $75,000. The company was engaged upon Government contracts. G. D. Berry is president.

ST. LOUIS.—The Tri-City Steel Company is planning for the construction of a new one-story steel rolling mills, about 100 x 390 feet, at Madison, Ill.

ST. LOUIS.—The Certain-teed Products Corporation has acquired a tract of land comprising about six acres on Union Avenue, between Brown Avenue and the Terminal tracks, as a site for the construction of a new plant for the manufacture of paints. The plant will be a four-story concrete building, and will have a capacity of about 4,000,000 gallons per year. Plans are now in course of preparation by Klipstein & Rathman, St. Louis.

ST. LOUIS. — The St. Louis Coke & Chemical Company is planning for the erection of a large new plant, including a by-product coke oven and two blast furnaces, on a site comprising about 300 acres recently acquired, near Granite City, Ill. The property was purchased for a consideration said to be in the neighborhood of $200,000. The new works will engage in the manufacture of toluol, ammonia, naphtha, benzol, metallurgical and domestic coke, gas, etc., and the project is estimated to involve an expenditure of approximately $5,000,000. L. E. Fisher is vice-president and general manager.

KANSAS CITY.—The Patent Vulcanite Roofing Company has had plans prepared for the construction of a new one-story addition to its plant on Twelfth Street, about 90 x 150 feet.

MONTANA

SALTESE. — The Tarbox Mining Company is planning for the early construction of a new 300-ton concentration mill. Richard Daxon is manager.

NEBRASKA

OMAHA.—The L. V. Nicholas Oil Company is having plans prepared for the construction of a large new refinery, to have a capacity of 1,000 barrels daily. The company has awarded a contract for the construction of a new 100,000 gallon tank to be located on property recently acquired at Twenty-fourth and Hickory Streets, comprising approximately nine acres.

NEVADA

MINA.—Frank Manson, connected with the Western Ore Purchasing Company, has acquired the old Candelaria silver mine, and is planning for the construction of a new 150-ton mill.

NELSON.—The Allard Mining Company is planning for the installation of a new tube mill and centrifugal amalgamator at the Carnation mine, for the treatment of high-grade ore.

NEW MEXICO

MOGOLLON.—The Socorro Mining Company has commenced the construction of its main mill building at its plant. Immediately upon completion of the structure, machinery will be installed, deliveries of which have started.

NEW JERSEY

NEWARK. — The Central Dyestuff & Chemical Company, Plum Point Lane, is having plans prepared for the construction of a new reinforced-concrete addition to its plant. Marshall N. Shoemaker, 810 Broad Street, Newark, is architect.

NEWARK.—The Mono Service Company, Verona Avenue and Oraton Street, has taken out a building permit for the construction of a new brick factory, to be used as an addition to its paper products manufacturing plant. The works will cost about $15,000.

NEWARK.—The Heller & Merz Company, Hamburg Place, manufacturer of chemicals, etc., has had plans prepared for alterations and improvements in its plant.

NEWARK.—Fire, on March 24, caused by an explosion, destroyed three buildings at the plant of the Butterworth-Judson Corporation, Avenue R, manufacturer of chemicals, with total loss estimated at $200,000. The company is working on large Government contracts.

EAST ORANGE.—The Dunbar Sulphur Candle Company has filed authorization papers to operate at 65-67 Midland Avenue for the production of sulphur candles. William C. Lentz, 247 Clinton Avenue, West Hoboken, heads the company.

PLAINFIELD.—The Crescent Color Company, West Front Street, manufacturer of dyestuffs, etc., has commenced the construction of a new addition to its plant. The structure is estimated to cost $20,000.

MILLBURN.—Fire, on March 27, partially destroyed the plant of the Fandango Paper Company, Main Street, with loss estimated at $10,000.

TRENTON.—The Panther Rubber Manufacturing Company, of Stoughton, Mass., has recently purchased a factory building at the foot of Perrine Avenue for a consideration of about $25,000, and is planning to remodel and equip the plant for the manufacture of its products.

CAMDEN.—R. M. Hollingshead & Company, Ninth and Market Streets, manufacturer of soaps, greases, etc., have had plans prepared for the construction of a new three-story brick addition to its plant, about 60 x 150 feet, to cost $10,000.

NEW YORK

NEW YORK. — The Consolidated Metal Manufacturing Company, 130 Washington Place, has had plans prepared for the construction of a new one-story brick chemical manufacturing works to be located at Gold and Tillary Streets, Brooklyn.

NEW YORK.—The Central Smelting & Refining Company, 220 Rider Avenue, has filed plans for the construction of a new factory building, to be located in Canal Street, near Dalrymple Avenue, Woodhaven, L. I. The estimated cost of the structure is $25,000.

NEW YORK. — The Knowles-Bradley Company, 88 Wall Street, refiners of saltpetre, has awarded a contract for the construction of a new five-story brick plant, about 100 x 165 feet, in Coffey Street. The works will cost about $36,000. H. G. Larzelere, Sycamore Park, New Rochelle, is the contractor.

COLLEGE POINT, L. I.—The L. W. F. Engineering Company, manufacturer of aeroplanes, has recently filed plans for the construction of a new one-story brick addition, about 210 x 250 feet, to its plant at Third Avenue and Eighth Street. Contract for the structure, which will cost about $15,000, has been awarded.

MOUNT VERNON.—The Triplex Safety Glass Corporation of America has acquired a tract of seven acres of land along the New York, New Haven & Hartford Railroad, for a consideration said to be $80,000, as a site for the construction of a new glass plant.

BUFFALO.—Fire, on April 2, caused by an explosion, destroyed a portion of the plant of the National Aniline & Chemical Company, Abbott Road, with loss estimated at $30,000.

OHIO

CLEVELAND. — The General Chemical Company, Warner Road, has awarded a contract for the construction of two new additions to its plant to cost about $20,000. A. A. Lane Construction Company, 1836 Euclid Avenue, Cleveland, is the contractor.

CLEVELAND.—Fire recently destroyed a portion of the plant of the Lennox Chemical Company, which was engaged in the manufacture of anesthetics for the American Red Cross. Quantities of acids and gas being manufactured for the Government were also destroyed. The loss is estimated at $100,000.

CLEVELAND.—The Lake Erie Smelting & Refining Company has filed plans for the construction of a new foundry addition to its plant at 3363 East Seventy-fifth Street. The structure will cost $18,000.

MASSILLON.—The plant of the Massillon Electric & Gas Company was partially destroyed by fire on April 3, with loss estimated at about $250,000.

NEWARK.—The Holophane Glass Company has awarded contracts for the erection of a large new experimental plant on Oakwood Avenue, comprising tank, lehr, and general factory buildings. It is expected that the plant will be ready for operation before the end of the summer.

SPRINGFIELD.—The Ohio Steel Foundry Company is planning for the construction of two new additions to its plant near Lagonda, one to be one-story about 30 x 120 feet, to be used as a core room, and the other about 30 x 100 feet, to be used as a blast and repair shop. A new electric furnace will also be installed, of three-ton capacity.

OKLAHOMA

ELK CITY.—The Lucky Elk Mining Company has completed its organization plans, and will commence the development of about 40 acres of lead and zinc lands recently acquired.

PICHER.—The Picher-Oklahoma Mining Company is planning for the immediate construction of a new 800-ton mill at its properties. R. P. McReynolds is general manager.

PICHER.—The Crystal Mining Company is planning for the construction of a new 250-ton mill at its properties. B. B. Dancy is president.

OREGON

GRANTS PASS. — The Almeda Mining Company has awarded a contract for the construction of a new reduction plant at its copper-gold mine on Rogue River, near Grants Pass, the concentrator to have a capacity of 200 tons, and the blast furnace being of 150-ton capacity. The estimated cost of the plant is $200,000.

PENNSYLVANIA

GLENDON. — Fire, on March 25, destroyed a portion of the fertilizer plant of Berger Brothers, with loss estimated at $10,000.

PHILADELPHIA.—The Brown Instrument Company has just let a contract to R. C. Ballinger & Co. for an addition to its factory to cost approximately $50,000. This addition will be erected on the land which was purchased last fall at Wayne and Roberts Avenues, adjoining the present building.

PHILADELPHIA.—The Powers-Weightman-Rosengarten Company, manufacturer of chemicals, etc., has awarded a contract for the construction of a new one-story brick addition, about 45 x 60 feet, at 921-27 Brown Street.

PHILADELPHIA.—Charles Lennig & Company, Inc., 112 South Front Street, manufacturers of acids and chemicals, have had plans prepared for the construction of a new machine shop addition to their plant at Bridesburg, near Philadelphia, to cost about $17,000.

PHILADELPHIA.—W. H. & F. Jordan, Jr., Inc., 218 North Delaware Avenue, manufacturer of chemicals and allied products, has acquired the building at 124 Water Street, New York, for the establishment of a branch selling office. The new branch will be in charge of Warren E. Monroe.